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An Electromyographic Study of the Behavior of the Masseter and Temporal Muscles Before, During, and After Orthodontic Procedures: Part VII. During Final Stages of Orthodontic Procedures (Six Months Subsequent to Part VI)

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AN ELECTROMYOGRAPHIC STUDY OF THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES BEFORE, DURING, AND AFTER ORTHODONTIC PROCEDURES

Part VII: During Final Stages of Orthodontic Procedures (six months subsequent to Part VI)

by

H. GORDON OSSER

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LIFE

H. Gordon Osser was born in Ewen, Michigan, on April 7, 1927. He was graduated from Theodore Roosevelt High School in Los Angeles, California, in June, 1945. He enlisted in the United States Navy and served from May of 1945 through June, 1946. He was graduated from the Leland Stanford Junior University in June of 1949 and received the degree of Bachelor of Arts in Biology. He was accepted to the College of Physicians and Surgeons, School of Dentistry, in September, 1949 and received the degree of Doctor of Dental Surgery in June of 1953. Upon his graduation he began the practice of general dentistry in Alameda, California. He served part time at the College of Physicians and Surgeons as Clinical Instructor in Operative Dentistry from 1954 until 1960, when he was accepted to the Graduate School of Orthodontics at Loyola University School of Dentistry.

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CHAPTER I

INTRODUCTION

A. Introductory Remarks and Statement of the Problem

To find out what changes occur in the motor output to the muscles of mastication as a result of the sensory input during the process of orthodontic treatment, a longitudinal study was begun in 1959. This investigation, an electromyographic study of the behavior of the masseter and temporal muscles before, during and after orthodontic treatment, was divided into the following phases:

Part I — Before Treatment and One Day After Placement of Separating Wires. Dr. Bernard A. Widen, 1960

Part II — One Week After the Placement of Separating Wires Between the Teeth. Dr. Steve Asahino, 1960

Part III — One Week After the Placement of the First Archwires. Dr. Richard Shanahan, 1960

Part IV — During Anchorage Preparation. Dr. Eugene H. Zylinski, 1961

Part V — After Completion of Anchorage Preparation. Dr. Thomas W. Fleming, 1961

Part VI During the Final Stages of Treatment.
Dr. Ronald H. Roth, 1962

Part VII During the Final Stages of Treatment, Electromyographic Recordings Taken Six Months Subsequent to the Recording of Part VI. Dr. H. Cordon Osser, 1962

B. Review of Related Literature

1. Neuromuscular Mechanism

Frankel (1871), Black (1887), and Stewart (1927) all reached similar conclusions: that the power of localization in the tooth was due to the nerves of the periodontal ligament. Stewart produced evidence from pulpless teeth which indicated, as Frankel and Black believed, that pulpal nerves have nothing to do with touch and pressure sensation. He agreed that this sensation must be transmitted along the nerves of the periodontal tissues.

Pfaffman (1939), using electro-physiological methods to register action potentials in the dental nerves of cats, concluded that the periodontal ligament is so richly supplied with nerve endings that very slight pressure is adequate stimulus. Brookhart (1953) finds that pulpal fibers may show excitation without any periodontal membrane involvement.

Thus, research over the years proves the original premise that proprioception of the tooth is mediated through the nerve fibers of the periodontal membrane.

The periodontal ligament, according to Goldman (1953), Maximow and Bloom (1952), Noyes (1938), and Orban (1957), consists of principal and indifferent fibers. The indifferent fibers are loose connective tissue fibers. The principal fibers, all of which are attached to the cementum, consist of white collagenous connective tissue and cannot be lengthened. These fiber bundles have a wavy course permitting a change of position of the tooth when force is applied to it. Although the bundles run directly from bone to cementum, the single fibers do not span the entire distance (Orban, 1957) and are "spliced" together by an intermediate plexus of fibers which allows movement, i.e., eruption through readaption of the fibers in the intermediate plexus.

These principal fibers are arranged into six groups as follows: gingival fibers which attach the gingiva to the cementum; transeptal fibers which connect adjacent teeth; alveolar crest fibers which are found around the entire tooth, from tooth to surrounding alveolus, and counteract lateral forces on the tooth; horizontal fibers which run at right angles to the long axis of the tooth, directly to the bone; oblique fibers which run apically from alveolar bone to cementum at about a forty-five degree angle and counteract vertical forces; and apical fibers which descend from the apical portion of the tooth to the alveolar bone. These principal fibers hold the tooth in suspension, as well as absorb and counteract the stresses placed on the tooth.

The periodontal membrane has four functions (Goldman, 1953 and Orban, 1957): formative, supportive, nutritive, and sensory. The formative function operates in the production of new tissue--cementum, alveolar bone, and fibers of the periodontal ligament; the supportive function, in resisting various stresses through the maintenance of the tooth in its relation to the surrounding hard and soft tissue; the nutritive function, in furnishing the necessary substances through the blood vessels for the maintenance of metabolic activity; and the sensory function, in receiving of impulses and reaction to stimuli, operates through the nerves.

The actual anatomy and mechanism of the proprioceptive and pain fibers in the periodontal ligament have long been a source of disagreement between investigators. The first to use silver and gold stains to trace histologically the course of the terminal nerve fibers of the periodontal ligament was Dependorf in 1913. He found definite neural endings which were fine pointed processes in the cementoblastic region of the tooth. His findings were disputed by Kadanoff (1927), who obtained his material from two individuals who had been executed by hanging. Kadanoff had far more extended area for histological research than did Dependorf, who used only extracted teeth. Kadanoff ascertained that nerve fibers ran vertically from the apical region towards the gingiva; and that apical nerve fibers are re-enforced by accessory nerve fibers entering the periodontal membrane through foramina in the alveolar process. He established that the fibers loop back from the cementoblastic region into the periodontal ligament and end in terminal plexus and small knob-like swellings.

Van Der Sprenkel (1936), who did his work on mice, saw end rings which he said were neural endings. Bradlaw (1936), using monkeys in his experiments, could not find the terminal rings of Van Der Sprenkel, but did see the neural loops of Kadanoff turning back from the cementum. Bradlaw also found that nerves from adjacent teeth cross the interdental septum. He believed that it was through this connecting of periodontal ligaments throughout the jaw that one has coordination and control of occlusion in the act of mastication.

Lewinsky (1936), in studying teeth, decided that histologically the nerve fibers of the periodontal ligament end in fine arborizations. Many of the fibers do have terminal, knob-like bodies; but none of the fibers could be traced into the cementum of the teeth, he stated, thus verifying the work of Kadanoff.

That tactile and pressure stimuli came from the specialized end organs and were transmitted in the thick nerve fibers were the conclusions of Lewinsky and Stewart (1937). However, pain was transmitted through the delicate nerve fibers which end in fine arborizations without terminal end organs. This work agreed with earlier findings of Brashear (1936) who showed that pain is transmitted to a greater extent by sensory nerves of small diameter (less than six microns in diameter) and that tactile stimulus is transmitted by nerves of a larger diameter (six to nine microns in diameter).

In 1957 contradiction came to a head with evidence published by Bernick supporting the view of Dependorf, and a report published by Rapp, supporting the views of Kadanoff. Thus, the question of where the terminal fibers end is still in doubt. It is not the object of this thesis to enter into the dispute, but rather to point out that this question has not been settled. The point is that there <u>are</u> sensory terminations in the periodontal membrane which react in a manner analogous to that of the neural endings in the periodontal ligament of the mouse, as described by Van Der Sprenkel in 1936. Here we are told that the neural endings, which are rings, lie flatly on a collagenous tissue bundle which is not straight, but takes a slightly undulating course. As a result of the movements of the teeth, the collagenous bundle is stretched and the end ring changes form. It is that change in form that is the stimulus to the sensory nerves, and which gives perception of pressure.

The functions of nervous tissue are as follows: to receive stimuli from the environment; to transform such stimuli into nervous excitations; and to transmit these stimuli to the nervous center where appropriate responses are sent forth.

The nerve fiber, the axon, is a conductor along which the dynamic nervous excitation is propagated in waves--faster in large fibers than in small fibers. In the conduction of the excitation, the activity of one portion of the axon serves as a stimulus, activating the next portion; and so on, until the effector organ is reached. As the nerve becomes activated, it changes its electrical potential; and action currents then flow between active and non-active regions. Any stimulation, intense enough to cause the axon to respond, calls forth the maximum discharge, the "all or none phenomenon" of Lucas (1905 and 1909).

The cells which carry out the function of the nervous system are called neurons. They have a body made up of a nucleus plus surrounding cytoplasm which projects out from the cell body as a number of processes. These usually comprise several short dendrites which receive the stimuli and one axon (which may have a great length) for the transmission of the stimuli. All but the smallest axons are enveloped in a myelin sheath. The synapse, i.e., the area of contact between two neurons--the axon of one neuron and the dendrite of another neuron--transmit functional influence from one cell to another in one direction only. In their peripheral course outside the central nervous system, both myelinated and unmyelinated nerve fibers are bound into bundles by connective tissue, forming peripheral nerve trunks and their branches. At the terminal end of the nerve fiber, the axon carrying an impulse has a modified ending. The nerve fibers ending in muscles are either sensory endings--the neuromuscular spindles--or motor endings--the motor end plates of the muscle fibers.

The nervous center for muscle sense in the trigeminal nerve has long been considered to be the mesencephalic root (Sherrington, 1917, and Allen, 1919). Hinsey (1934) stated definitely that the proprioceptive fibers, passing out to the muscles of mastication in the motor root of the fifth nerve, arise in the mesencephalic nucleus of the fifth nerve. However, it was not until 1940 that Corbin and Harrison showed the course and distribution of the proprioceptive fibers of the trigeminal nerve. This work, done on cats, is correlated to studies of the distribution of nerves in humans. These men found that the mesencephalic root fibers, arising from the periodontal membrane, palate, and the muscles of mastication, mediate impulses which are inhibitory to the trigeminal motor nucleus cells. The total mesencephalic root inflow controls and coordinates the movements of the lower jaw and permits a forceful bite without damage to the structures involved in mastication (i.e., the teeth, the gums, the palate, and the temporomandibular joint).

The reflex mechanism of conduction of sensory and motor impulses which coordinate the action of mastication was first explained by Sherrington (1917) in his work on the decerebrated cat. Sherrington found that blunt pressure stimulation of the gums bordering the teeth of both upper and lower jaws, as well as the front part of the hard palate, caused a reflex opening of the tonically closed jaw. Upon withdrawal of the stimulus, there was a quick return to the previously closed posture--the rebound phenomenon common to anti-gravity muscles.

Reflex closing of the jaw accompanies the reflex swallow. Reflex jaw-closing is also evoked as a result of mechanical stimulation--e.g., by stroking the dorsum of the tongue near its tip with a feather. The tongue tip, in the closing reflex, curves slightly upward and is somewhat retracted, while at the same time the mandible raises and the mouth deliberately closes. This slow movement leads to no reverse action (opening) as occurs in the jaw-opening reflex. From this work Sherrington postulated the theory of reflex coordination of mastication:

> On the mouth's seizing a morsel, the mandible, when it has closed, e.g., voluntarily, upon whatever is between the jaws pressing it against the gums and teeth and hard palate, by so doing, as is clear from observation of the reflex, produces a stimulus, which reflexly opens the jaws. That done, the central rebound of the previously reflexly inhibited jaw-closing muscles, or rather of their motorneurons, for the inhibition is central sets in and tends to powerfully reclose the jaw again. The reclosure brings into operation once again the jaw-opening stimulus and so, after being started by a first bite, a rhythmic masticatory reflex tends to keep itself going so long as there is something between the teeth.

Corbin (1940) completely agrees with Sherrington's description of the chewing reflex in the light of his work on the actual distribution of the proprioceptive fibers of the trigeminal nerve. He describes the reflex action as follows:

> The pressure sensations elicited from the deeper tissues of the jaw would serve to control the force of the

bite, preventing damage to the teeth, gums, and palate. Impulses arising from the teeth (periodontal membrane), gums, and palate could then not only inhibit activity of the jaw closer through inhibition of the motor nucleus of V and thus, inhibition of the activity of the muscles of mastication, but also actively elicit jaw opening through reflex stimulation of the motor nerves supplying the mandibular depressors.

The muscles in this study, the masseter and the temporalis, resist the action of gravity (Szenthagothai, 1948); that is, these two muscles act as the elevators of the jaw (Gray, 1960, Sicher, 1960, and Grant, 1956). The masseter muscle consists of two portions: the superficial and the deep. The significance of this muscle division was explained by Denny-Brown (1929). He found that, when there are two portions to a muscle, the deeper one is usually slower in its contractions and in its relaxations than the superficial part. As a result of the difference in contraction rates, the deeper portion responds to an increase in stimulus by a longer period of contraction; and the superifical portion responds (to an increase in stimulus) by an increase in tension. The superfical portion of the masseter arises from the anterior and middle regions of the zygomatic arch; the deeper portion from the middle and posterior regions of the zygomatic arch. Both parts insert together in the lateral surface of the ramus of the mandible. The nerve supply is from the mandibular division of the trigeminal nerve.

The temporal muscle is a fan shaped muscle, originating from the temporal fossa and the internal surface of the temporal fascia. The fibers converge as they descend and end in a tendon which passes deep to the zygomatic arch and is inserted into the coronoid process. The fibers can be divided into three divisions: anterior, middle, and posterior (Robinson, 1946, and Sicher, 1960). The anterior fibers are perpendicular to the occlusal plane; the fibers in the middle portion become increasingly oblique; and the fibers in the posterior portion are parallel to the occlusal plane. These posterior fibers, bending downward and forward in front of the articular eminence, insert into the coronoid process. (Carlsoo, in 1952, further divided the temporal muscle into two portions: medial and lateral. This further division is not considered in standard texts of anatomy such as Gray's-1960, Sicher's-1960, and Grant's-1960 but such division points to the pennate arrangement of the muscle fibers.)

The temporal muscle is built for movement rather than for power. Temporal and masseter muscles compliment each other in the elevation of the mandible. The temporal is innervated in the anterior, middle, and posterior portions of the muscle by branches from the mandibular division of the trigeminal nerve.

2. Electromyography

The history of electromyography is the story of the discovery and application of electricity and electronics to physiology. Modern electromyography dates back to 1901 (Licht, 1955) when Einthoven made modifications to the coil galvanometer which resulted in the string galvanometer. In 1907, Piper used this string galvanometer to measure the action potential of the forearm flexors and reported a fixed frequency rhythm of approximately fifty cycles per second. He noted that a change of intensity is accompanied by a change of amplitude and not of frequency. (This was not true as shall be seen.) Buchanan (1908), using a capillary electrometer, couldn't confirm the so-called "Piper-rhythm", and recorded electrical activity of the same muscle group at 40-120 cycles per second.

Liddell and Sherrington (1924) explained the stretch reflex, the myotatic reflex. Sherrington (1925) showed that the electrical potential eminated from a functional unit in reflex or voluntary activity, the motor unit. He defined this motor unit as the anterior horn cell, its axon process, and the group of muscle fibers which this cell innervates. The conduction of the stimulus along the fine intra-muscular branches of the anterior horn cell axon occurs so rapidly that all muscle fibers in a motor unit are activated nearly simultaneously. It is the change in electrical potential of the motor unit that is recorded on the electromyogram. Beritoff (1925) explained the spacial arrangement of the motor units within the muscles. Fulton (1926) explained the electromyogram in voluntary contractions as the summation of the action currents from the whole muscle.

Adrian and Bronk (1928) showed that the number of motor units fired depended upon the frequency of impulses in the nerve and thus disproved Piper's theory. This meant that the intensity of contraction of a voluntary muscle was due to the frequency of the impulse. Their work was facilitated by the development of the coaxial needle electrodes (Adrian and Bronk, 1928B).

Craib (1929) showed that the deflections resulting from activity on an isolated muscle preparation depended upon the amount and distribution of the conducting medium that surrounds the muscle and upon the position of the electrodes within this medium. He found an electrical field in the medium surrounding the muscle which varied, depending on the medium.

With the work of Adrian and Bronk, electromyography became a practical tool for the diagnostician (Bauwen, 1948). Sherrington and Eccles (1930) showed that the action of muscle is managed by the activation of only a portion of the motor units that are available in a given muscle. Pritchard (1930) showed that the electromyogram yields different myograms of the same muscle when it is used as an agonist, an antagonist, or as a synergist in the different movements of the limbs. Smith's findings (1943) confirmed the work of Adrian and Bronk.

Hoefner (1939) showed that the absolute refractory period of muscle is about .5 of a millisecond.

Miles, in 1947, reviewing electromyography, stated that it was generally agreed that the resting muscle is electrically inactive; that slight voluntary movements produce measurable potentials; and an increased contraction is accompanied by an increase in amplitude and frequency. He wrote, "The electromyogram may serve, therefore, to indicate whether or not a particular muscle is active during a prescribed movement and the relative degree of activity." It was soon shown that electromyography could easily be used in dental studies to great advantage.

3. Dental Electromyography

Ballard (1948) showed that electromyography could be used to demonstrate the degree of circumoral contraction that is necessary to enable a child with incompetent lip musculature to effect a seal.

Moyers (1949) investigated the muscle contraction patterns in malocclusion and normal occlusions. He found that electromyograms of the temporal muscle in normal occlusion showed: 1) there is a synergistic action between anterior, middle, and posterior bellies of the temporal muscle of the right and left sides; and 2) an even state of tonus is exemplified by uniformity of the spike potentials with regard to size, character, and frequency. His studies led to the conclusion that occlusion of the teeth is often a factor in the pattern of muscular function.

Moyers (1950) studied the actions of the muscle in the movements of the temporomandibular joint. He related each of the masticatory muscles to their role in their mandibular movements. He found that the function of the temporal muscle does not change appreciably with age. There are, however, temporary alterations in the electromyographic pattern of adolescents, resulting from temporomandibular adjustments to the arrival of new teeth. As the teeth settle into correct occlusion, these alterations are lost and the original spike pattern once more appears. This temporary alteration indicates the influence of proprioceptive impulses, arising from the newly erupting teeth, on the pattern of muscular contraction.

Pruzansky (1952) described qualitative differences in the electromyographic patterns of chewing. He established that synergistic behavior of the masseter and temporal muscles varied with the occlusion of the teeth. Certain extremes of muscular behavioral patterns he characterized as "choppers" and "grinders".

Carlsoo (1952) determined the total number of muscle fibers in the temporal and masseter muscles and also the number of motor nerve fibers which supplied these muscles. He concluded that the ratio between the number of muscle fibers and motor nerve fibers would give a mean value of the size of the motor unit. The mean diameter of the nerve fiber in the temporal muscle is twenty microns; and in the masseter, twenty-one microns. He could not establish the difference between efferent and afferent fibers. Distribution of fiber size within the nerve trunks showed that the temporal and masseter had a bi-modal transmission of nerve impulses. Some of the other fibers are probably tonic motor-neurons and small nerve fibers supplying the intrafusal muscle fibers in muscle spindles. His work on muscle action in mandibular postural movements agreed with that done by Moyers.

Tulley (1953) showed electromyography to be a good orthodontic tool for assessing changes in behavior of muscles before and after orthodontic treatment.

Perry and Harris (1954) found in normal occlusion that: 1) the temporal and masseter are synchronized as they reach maximum activity; 2) the temporal muscle always displays electrical activity before the masseter; 3) the amplitude was in direct proportion to the resistance of the bolus chewed. In the Class II, Division 1 (Angle Classification) malocclusion, the temporal and masseter muscles reached maximum activity asynchronously.

Jarabak (1954) showed how the temporalis and masseter muscles adapt to changes from proprioceptive stimuli which originate in the teeth, periodontal membrane, and the proprioceptors of the muscles. His work was done on a patient who had an excessive interocclusal space (17 mm.), and electromyograms were taken before and after insertion of a splint which reduced the large interocclusal space. Before the insertion, the masseters were electrically silent. After placement and reduction of the excessive interocclusal space, the masseters assumed an active role in mastication.

Jarabak also developed the schematic diagraming of the myogram which will be used in this paper. He explains as follows:

> The form of the myogram points out, in variations in

> amplitude, when the activity in the muscle begins, whether it occurs gradually, rapidly, or intermittently. It also shows whether its onset is slow or rapid and whether the decrease in its amplitude after the maximum contraction has been spent is slow or rapid. From this we can see that many combinations in form may be obtained.

Jarabak agrees with Perry and Harris on the synchronous phase of the masseter. He says:

> In normal occlusion, the ipsilateral temporal and masseter muscles enter into the phase of contraction at about the same time as the contralateral temporal and masseter muscles. In other words, all four muscles begin to show activity at the same time in each contraction cycle. This is synchronous contraction.

Perry (1955) discussed the dominant role of the temporal muscles in the mandibular closure, but stated that several Class II, Division 1 malocclusions had the masseter beginning the closure. In a second paper Perry (1955B) showed that muscle pain was due to spasms and suggested future research on the problem.

Greenfield and Wyke (1956) showed that the temporal muscle has the greater activity in biting in centric occlusion; their work indicates that all movement of the temporal and masseter muscles involves reflexively coordinated contraction and relaxation of the two muscles.

Jarabak (1956) showed three factors are distinctly dependent on each other for the correct functioning of the temporomandibular joint: the occlusion of the teeth, the temporomandibular joint, and the muscle balance. He says:

> Stimuli originating in the teeth can make a muscle spastic where spasticity did not previously exist. Tooth stimuli manifest their effect on patterns of muscular activity only when the teeth in the upper arch are in a certain position to the teeth in the lower arch. Vertical dimension (interocclusal space), as well as occlusal interference, cause spasticity.

Perry (1956) demonstrated spasticity in the muscle and associated it with pain.

Hicky (1957) studied mandibular musculature in basic jaw movements and affirmed that electromyography does not indicate movement in a muscle, but only shows increase or decrease in electrical activity.

Szirmai (1957) used the electromyogram and myotonometer to test functionly the force of the masticatory muscle before and after dental restorations.

Woefel, et al (1957) showed by electromyographic means that the external pterygoid muscles did not show increased electrical activity during hinge opening of the jaw.

Marvskaya (1959) studied the development of proprioceptive reflexes in the muscles of mastication. She found in her work on kittens, who varied in age from two hours to thirty days, that the greatest activity in the masseter occurs while feeding.

Vyklicky and Kaolva (1959) throw doubt on the time-honored theory of Sherrington (1925) that anti-gravity muscles have continuous electrical activity: they could not detect the so-called spontaneous activity of the muscles of mastication in rest position. This same conclusion had been reached by Ralston, et al (1953), regarding the postural muscles. Ralston feels that it is the elasticity of the muscle fiber itself, and not a constant electrical barrage contracting the muscles, that keeps the body erect.

In a study of malfunctioning of the motor mechanism of mastication, Tulley (1959) used methods similar to those used in medicine to determine the area of damage of the brain. He states that by immediate treatment the development of pathologic changes in mastication, such as the misuse of masticatory force, can be avoided.

Ahlgren (1960) studied the effect of the "activator" on the muscles of mastication and came to the following conclusions: 1) greatest muscle response was seen in mandibular protractors and simultaneous inhibition of the retractors; 2) removal of the appliance shows a reversal of muscular patterns for the first two hours and than a return to normal; 3) intermittent muscular activity of the activator is due to swallow.

rather than muscle stretch; 4) orthodontic treatment can change reflex activity to new and favorable contraction patterns.

Porritt (1960) studied proprioception electromyographically. He found that a single restoration with occlusal interference is sufficient to change muscular contraction patterns. In fact, he learned that such interferences inhibit muscular activity during mandibular movements. An interesting point of Porritt's which illustrates the minute tactile sense of the teeth, is that the location of interference on the tooth was more important than the location of the tooth in the mouth. The temporal muscle was more sensitive than the masseter in response to occlusal interference.

Fleming and Zylinski (1961) in re-evaluating the data for the first three experiments of this longitudinal study done by Widen, Asahino, and Shanahan and combining this data with the results from their own experiments gave the following synopsis of the study so far:

> The data from the original malocclusion (Experiment I) showed that the length of the chewing stroke was shorter at this time than at any other time during this study. As treatment progressed (Experiments II through VI), there was a continuous increase in the length of the chewing stroke. After the completion of anchorage preparation (Experiment VI), the length of the chewing stroke was longer than at any other time during this study. The continuous increase in the portion of the chewing cycle occupied by the chewing

stroke, from the original malocclusion (Experiment I) through the completion of anchorage preparation (Experiment VI), showed that it took longer to bite through the cough drop as treatment progressed. The significant factor governing these changes was that the subjects became more cautious in their chewing because the teeth and surrounding tissues were painful. This caution exhibited during mastication was expressed on the electromyogram by a longer chewing stroke.

CHAPTER II

METHODS AND MATERIALS

A. Selection of Subjects

Sixteen patients between ten and fourteen years of age were selected for this study by the original investigators from the Orthodontic Clinic of Loyola University School of Dentistry. These patients presenting either Class I or Class II (Angle Classification) malocclusions were considered for treatment with a technique that utilized light, resilient wires, and light elastic forces. It is to be noted that two years had elapsed since the beginning of the study (the fall of 1959), and the time when this portion was completed (the fall of 1961).

B. Muscles Studied

The posterior and middle fibers of the right and left temporal muscles, plus the right and left masseter muscles, were selected for this study because of their function in mastication and their accessability for the placement of surface electrodes. The middle temporal fibers act as elevators of the mandible. The posterior temporal fibers are concerned with lateral and posterior movement of the mandible. The masseter muscles provide power for elevating the mandible. Myograms of the muscles on both right and left sides were recorded simultaneously.

C. Electromyographic Equipment

The electromyographic equipment (Figure 1) consisted of the following: an eight channel G.M.E. polygraph which was modified to record electromyographic voltages; a channel on the polygraph altered to accept electrical impulses from the bone conduction microphones; a microvolt calibrator built into the polygraph; and a Faraday cage within which was mounted an electrode terminal board. Patients were seated in the Faraday cage while the records were taken. The Faraday cage reduced extraneous electrical activity to an isoelectric point.

The amplifiers and compensating filters of the polygraph were set to give the greatest fidelity of transmission. The pen deflection was calibrated before and after each experiment. This calibrating was done to check whether or not the system was operating uniformly throughout the full range of deflections that might be expected. The measurement of the pen deflection was 11.5 mm. on either side of the central base line for a 500 microvolt peak. The paper speed was set at six centi-

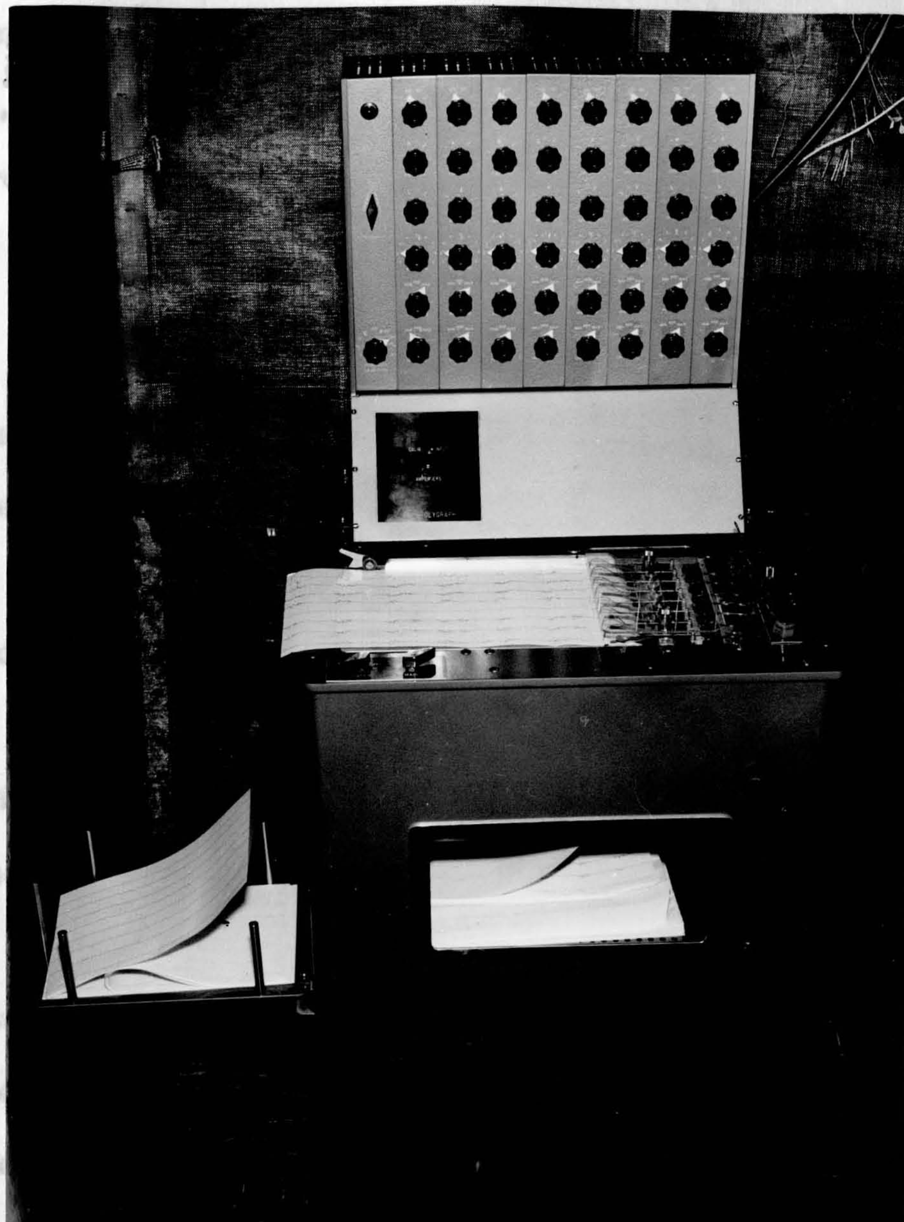


FIGURE 1

G.M.E. POLYGRAPH

meters per second. The vertical lines on the paper were printed 6 mm. apart; and, at the aforementioned paper speed, the interval between two lines represented .1 of a second.

D. Sound Equipment and Recordings

The components of the sound system (Figure 2 and Figure 3) were a bone conduction microphone (Zenith Hi-Lo, Regent Type), a matching transformer (Shure Model A86A), a pre-amplifier (Heathkit WA-P2) and necessary power supply for pre-amplifier, and a tape recorder (Wollensak Stereo Model T-1515), and one channel of the polygraph.

The bone conduction microphone (Figure 4) was placed on the subject's forehead and held in position by a spring type headband. The microphone was connected through the matching transformer to the pre-amplifier. The output of the pre-amplifier went to the polygraph and to the tape recorder, which was set at a tape speed of 7 1/2 inches per second. The settings of the tape recorder were as follows: volume level, 5; tone control, treble; and monitor switch, on. The sounds of the chewing and tapping exercises were monitored through the tape recorder. This procedure was done to insure proper performance of the exercises. The output from the pre-amplifier entering a channel of the polygraph

FIGURE 2

SOUND EQUIPMENT AND FARADAY CAGE

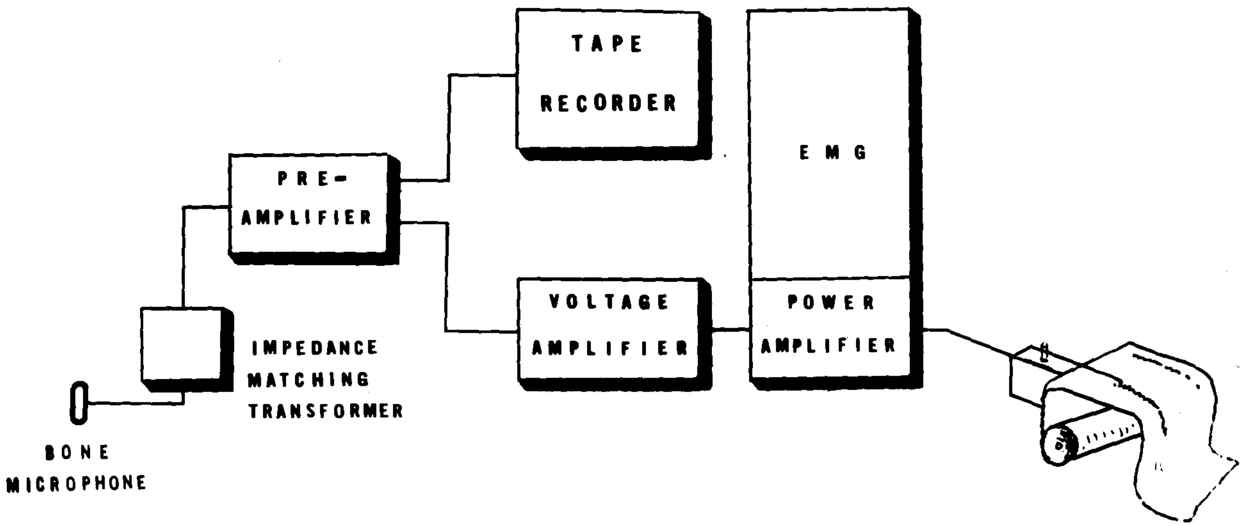


FIGURE 3

DIAGRAM OF THE SOUND SYSTEM

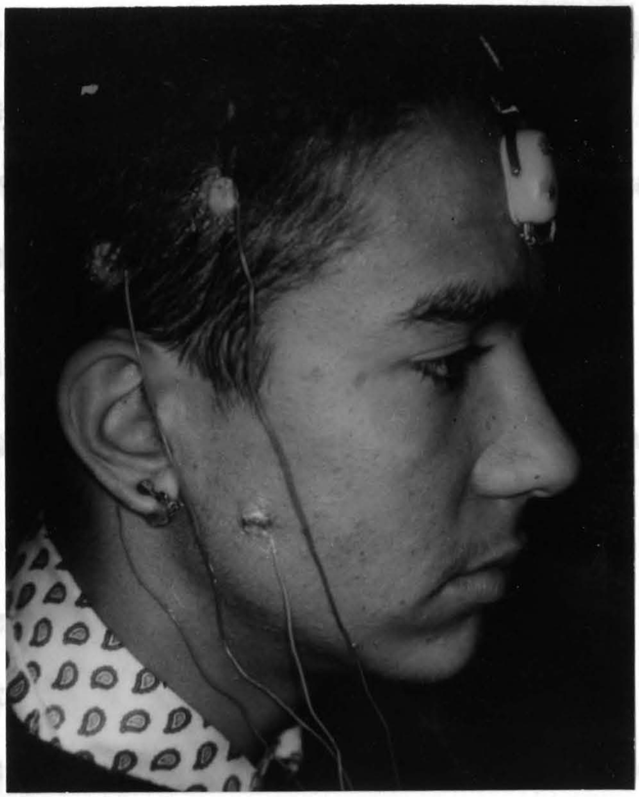


FIGURE 4

PLACEMENT OF THE BONE CONDUCTION MICROPHONE AND THE ELECTRODES was converted by it into "sound tracings". These, called "sonograms" and described by Widen (1960) in the first part of this study, were simultaneously recorded with the myograms. The sonograms, which correspond to the tapping and chewing sounds emitted during the test exercises, consisted of a base line and deflections from it--spikes--of varying amplitudes, frequencies, and durations.

E. Chewing Medium

The chewing medium used was Vick's cherry flavored cough drops, selected because of their uniform size and hardness.

F. Electrodes and Electrode Placement (Figure 4)

Two types of surface electrodes were used. One was a metal clip which was fastened to the ear. This served as the reference electrode.

The other was a monopolar disc, silver surfaced, and five-sixteenths of an inch in diameter. This type was used in preference to others, because the temporal and masseter muscles lie close to the skin on the side of the head--absence of underlying superficial or adjacent muscle tissue made this electrode very satisfactory for studying muscular behavior. The surface electrodes were placed bilaterally on the masseter muscles midway between their origin and their insertion. Electrode placement was determined by instructing the patient to clench his teeth and then relax. The desired area on the muscle was located through palpation. Where necessary, the hair was trimmed, exposing an area approximately one-half inch in diameter so that the electrode could be placed in immediate contact with the skin.

The areas where both types of electrodes were to be placed were cleansed with soap and water, rubbed with acetone, and then rubbed with electrode jelly. The disc was held in place by colloidin. Electrode jelly was then forced into the space between the inner surface of the disc and the skin by using a blunted eighteen gauge needle and a Luer-Lok syringe. The jelly was also placed around the ends of the clip before it was fastened to the ear.

The skin resistance was checked with an ohmmeter to be sure that the skin resistance was less than 5,000 ohms. A low skin resistance allowed a greater pickup of low amplitude electrical potentials by the electrode. This measure of skin resistance had been standardized at the beginning of the study.

G. Experimental Procedure

The subject was seated in a Faraday cage; the electrodes were attached to the patient as previously explained; the leads from the electrodes were connected to the terminal board in the Faraday cage; and the bone conduction microphone was placed on the patient's forehead. A printed list of instructions was given to the patient and the procedure explained. The subject was told to recite each item on the list, which was automatically recorded on the tape, and then to perform the required exercises: (1) resting, (2) tapping teeth in centric occlusion, (3) chewing a cough drop on the right side of the mouth, and (4) chewing a cough drop on the left side of the mouth.

(The chewing exercises were selected for two reasons: first, the act of chewing is mainly reflex in nature and therefore relatively free from the influence of both subject and experimenter; secondly, chewing the cough drop subjected the teeth, their supporting structures, the muscles, and the joints to stresses which tested their functional ability.)

To facilitate the resting procedure, the patient was instructed to relax, close his eyes, allow his arms to lie passively in his lap, place his feet flat on the floor, and hold his head in such a manner that the

Frankfort horizontal plane was parallel to the floor. When the polygraph showed minimum movement, this indicated muscular rest which was recorded. At the beginning of the chewing exercises, the subject placed the cough drop between the teeth on the designated side and was told to chew slowly and firmly ten times. Duplicate exercises were performed to minimize the experimental error. Tape recordings of all recitations and exercises were made along with the myograms and sonograms.

Recordings were taken in Experiment VIII in the same manner as in Experiment I. Similar instructions were given and complete records taken as before with this exception: that since a different electromyographic machine was now being used, it was possible to record all muscles of both sides simultaneously.

H. Orthodontic Procedure

Each subject's teeth were banded. Brackets on the bands of the posterior teeth--the bicuspids and molars--were angulated from the horizontal to give the teeth a distal tip-back when a straight wire was placed in the bracket slots. Mandibular brackets were angulated eight degrees from the horizontal; the maxillary brackets, five degrees.

The maxillary and mandibular central and lateral incisors had brackets angulated two degrees from the horizontal to give the incisors a mesial convergence for artistic positioning. Brackets for the maxillary canines were not angulated, whereas the brackets for the mandibular canines were angulated seven degrees from the horizontal for mesial tipping. All brackets, except the maxillary canine brackets, were torque slotted so that, when a rectangular archwire was placed into the brackets, the teeth would assume an ideal axial inclination labio-lingually.

This part of the study in the final stages of orthodontic treatment, included: (a) consolidation of space, (b) correction of the molar relations, (c) leveling of the occlusal plane, (d) final artistic positioning of the teeth, and (e) "seating" of the occlusion.

The archwires used in the treatment of the malocclusions were made of Elgiloy-semi-spring wire, which is very resilient and directs a light force to the teeth. Three different sizes were used: a round wire, 0.016 inch in diameter; a square wire, 0.016 inch by 0.016 inch, and a rectangular wire, 0.016 inch by 0.022 inch. The round wire was used for all active phases of treatment, except where torquing was required.

When this was required, the square or rectangular wire was used because it would not slip in the brackets; the round wire would do this. Square and rectangular archwires were also used for artistic positioning of the teeth.

The several configurations of the archwires used in the final stages of treatment are: the consolidation archwire, the vertical contraction loop archwire, the straight (horizontal) archwire, the straight (horizontal) archwire with attachments, and the ideal rectangular archwire. All of these are first fashioned in the shape of an ideal arch. Each is individualized in arch width and arch form for each patient, and all are used in both jaws. They differ as follows:

The Consolidation Archwire (Figure 5)

A bent-in hook is made in this archwire between the cuspid and the lateral incisor on both right and left sides which is designed to fit closely to the distal surface of the bracket of the lateral incisor. This archwire has elastics, stretched from the bent-in hooks to the molars to close spaces between the anterior teeth.

The Vertical Contraction Loop Archwire (Figure 6)

Two closed vertical helical loop springs, one on each side of the

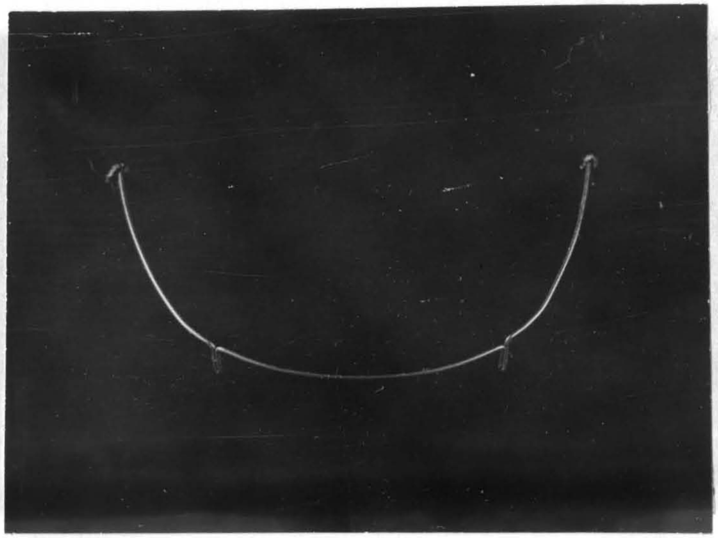


FIGURE 5

THE CONSOLIDATION ARCHWIRE

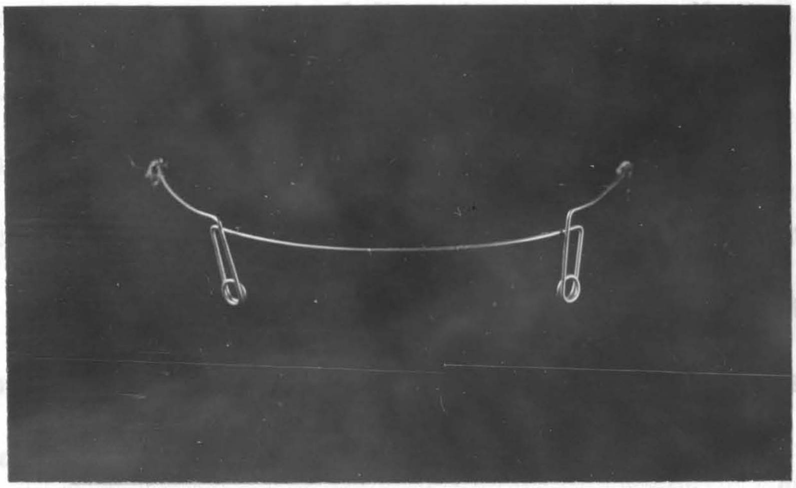


FIGURE 6

THE VERTICAL CONTRACTION LOOP ARCHWIRE

archwire, when activated, close the spaces remaining between the posterior teeth.

The Horizontal Loop Archwire (Figure 7)

Here, horizontal helical loop springs are used as the activating force to move teeth in a vertical direction, so that all the teeth are on a level occlusal plane.

The Straight (Horizontal) Archwire (Figure 8)

This archwire carries no attachments, helical loops, nor bent-in hooks. It is used primarily for correcting minor movements of the teeth and for keeping one arch in good alignment while final adjustments are being made on the other one.

The Straight (Horizontal) Archwire with Attachments (Figure 9)

This differs from the previous archwire (Figure 8), in that it carries two sliding hooks and two lengths of .010 inch closed coil. These, placed on each side of the archwire, slide freely on it. The force on the sliding hooks of stretched elastics are advanced to either the bicuspid or molar by the closed coils. The bands on the canine teeth are removed in order to allow the closed coil and the sliding hook to move freely on the archwire.

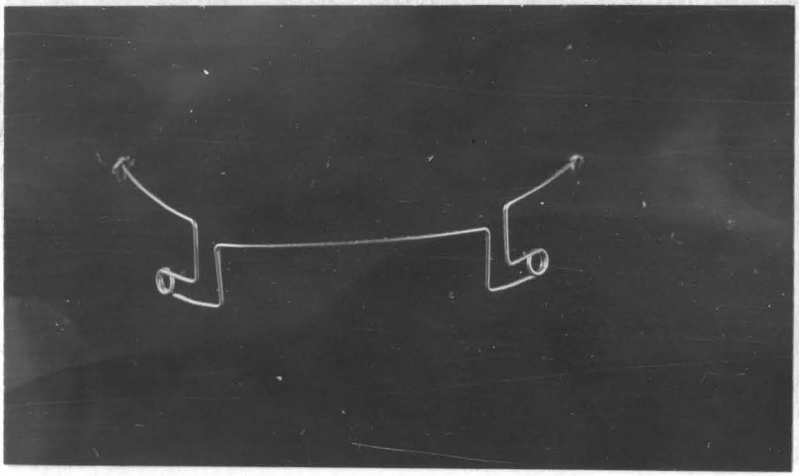


FIGURE 7

THE HORIZONTAL LOOP ARCHWIRE

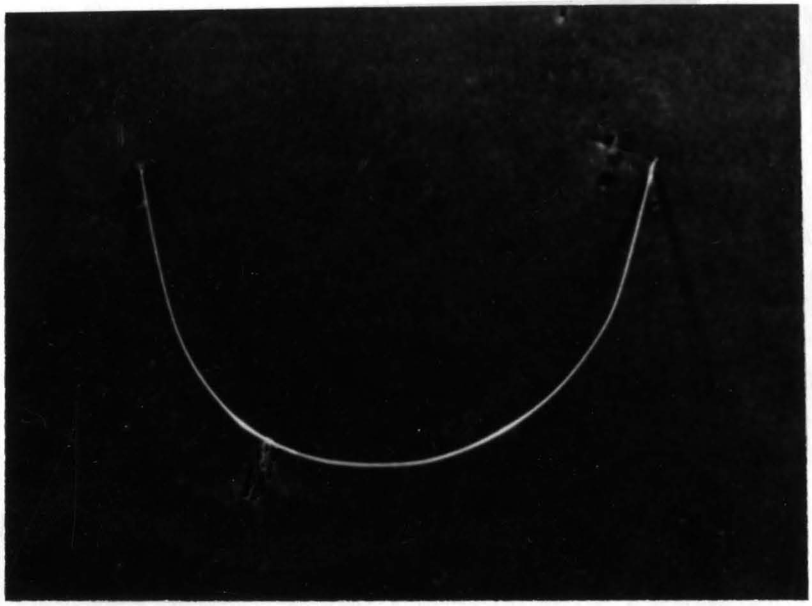


FIGURE 8

THE STRAIGHT (HORIZONTAL) ARCHWIRE

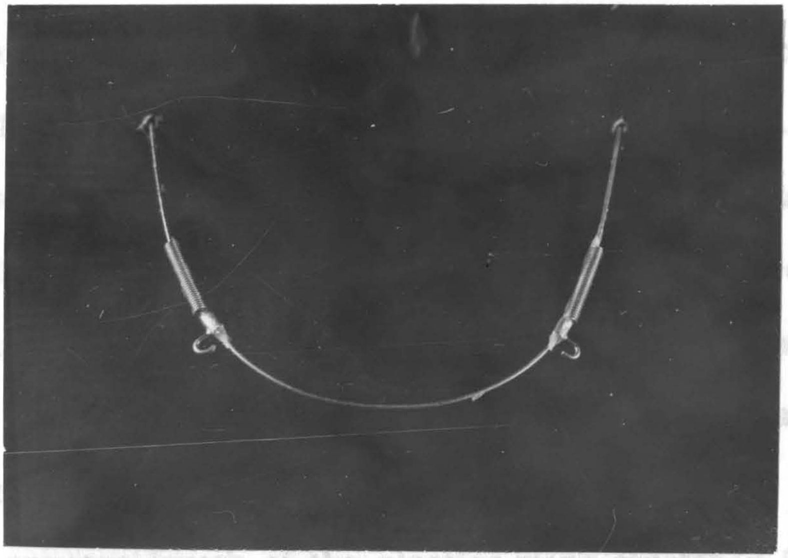


FIGURE 9

THE STRAIGHT (HORIZONTAL) ARCHWIRE

WITH ATTACHMENTS

The Ideal Rectangular Archwire (Figure 10)

The maxillary arch has first order bends for the lateral incisors, but the mandibular ideal archwire does not include such bends. First order bends for the canines and molars are made in both arches. The archwires carry no attachments, and are used, in certain cases, for final positioning of the teeth before the bands are removed.

The elastics used in conjunction with the archwires just described were: (a) light one-quarter inch latex elastics which exerted an average pull of two ounces when stretched one and one-quarter inches, and (b) heavy one-quarter inch latex elastics which exerted an average pull of four ounces when stretched one and one-quarter inches. This distance is about the average length of the elastics were stretched in the mouths of the patients during the treatment of the malocclusions. The elastics were worn bilaterally in the following ways:

1. A light intermaxillary elastic stretched from a hook (located on the lingual surface of the band on the mandibular first molar) to the maxillary jaw where it was either hooked to the bent-in hook on the consolidation archwire or to the sliding hook of a straight archwire.

2. A light intermaxillary elastic stretched from the end of the

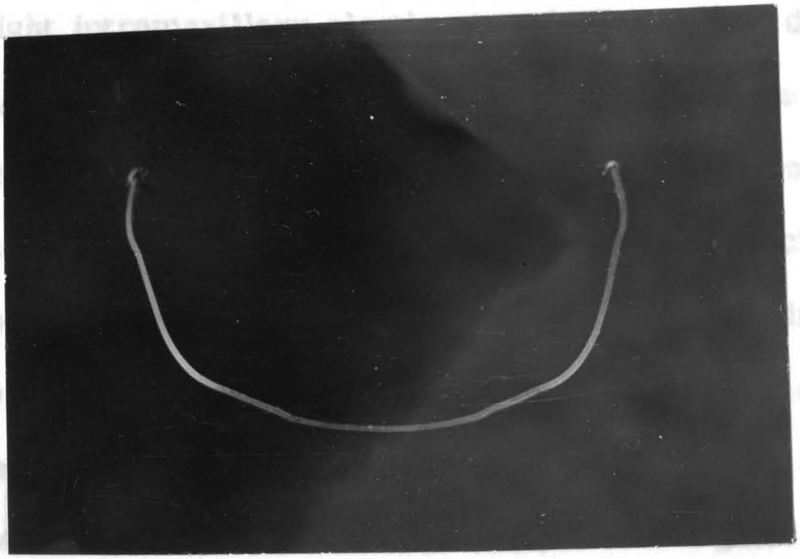


FIGURE 10

THE IDEAL RECTANGULAR ARCHWIRE

mandibular archwire (which protruded beyond the distal end of the buccal tube of the mandibular first molar) to either the bent-in hook of the consolidation archwire or the sliding hook on a straight archwire in the maxillary jaw.

3. A light intramaxillary elastic stretched from the distal end of the mandibular archwire (protruding through the molar tube on the buccal surface of the mandibular first molar) to the bent-in hook, located distally to the bracket of the mandibular lateral incisor.

4. A heavy intermaxillary elastic was worn buccally in the shape of a triangle. The elastic was hooked in three places: (a) over the portion of the maxillary archwire (which protruded distally from the buccal tube of the maxillary first molar); (b) over a ligature tie on the maxillary second permolar; (c) over a ligature tie on the mandibular second premolar.

High-pull headgear was used in conjunction with the consolidation archwire to keep the crowns of the anterior teeth from tipping lingually during that phase in treatment when the spaces between these teeth were being closed. This high-pull headgear is an extra-oral device and consists of two headgear hooks, two (or more) elastics, and cloth belting.

The hooks are attached to the maxillary archwire between the maxillary lateral and central incisors and are placed under tension by means of "X" type of Orthospec Elastics. These elastics are stretched from the headgear hook to a hook riveted onto the cloth belting. The cloth belting fits over the head; the skull is used as the means of keeping the elastics stretched and causing tension on the maxillary archwire. The force exerted by this appliance is between nine and twelve ounces.

Some of the patients were in retention at the time this part of the experiment was done and were using rubber finishing appliances (Figure 11) made of vulcanized rubber, resilient in nature, and constructed to move the teeth gently, through functional exercises, into their final ideal positions. After the occlusion was thus "seated", these appliances were used as retainers.

I. Utilization of Sound Data to Interpret the Electromyograms

The data consisted of myograms, sonograms, and tape recordings of the temporal and masseter muscles taken during tapping, chewing, and at rest procedures. The myograms and sonograms taken at rest permitted an evaluation of the base line or minimum activity in the muscle and sound channels. Myograms, compared with the sonograms

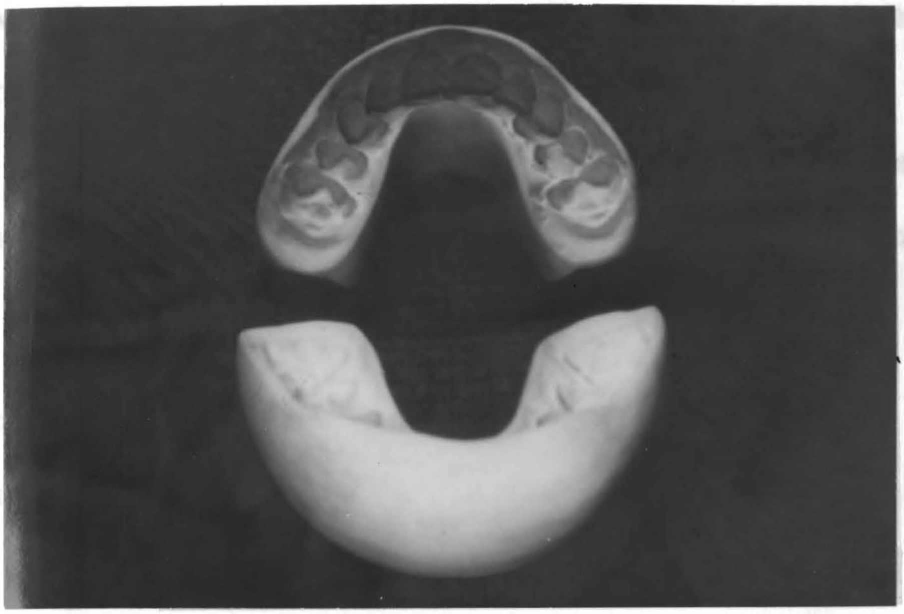


FIGURE 11

THE RUBBER FUNCTIONAL FINISHING APPLIANCE recorded during tapping exercises, showed a correlation between tapping sounds and muscular activity. The sound of the teeth meeting in centric occlusion, as in the tapping exercise, produced a sharply defined monophasic or polyphasic sonogram (Figure 12). The position of the first sound spike was marked and then projected on the myogram for each muscle. The beginning of the chewing cycle could be identified as that part of the myogram showing electrical activity preceding the sound spike.

J. Selections of the Myograms for Study

The myograms from the first three chewing strokes of the right and left side of duplicate exercises were selected for study. The succeeding chewing attempts (there were ten in each exercise) were not studied because the cough drop became an unmanageable tacky mass and afforded little or no resistance to chewing. A total of thirty-six myograms, taken from three muscles during the first three chewing strokes of the four chewing exercises of each experiment, were analyzed and compared to the analagous three chewing strokes of the previous experiments in this study.

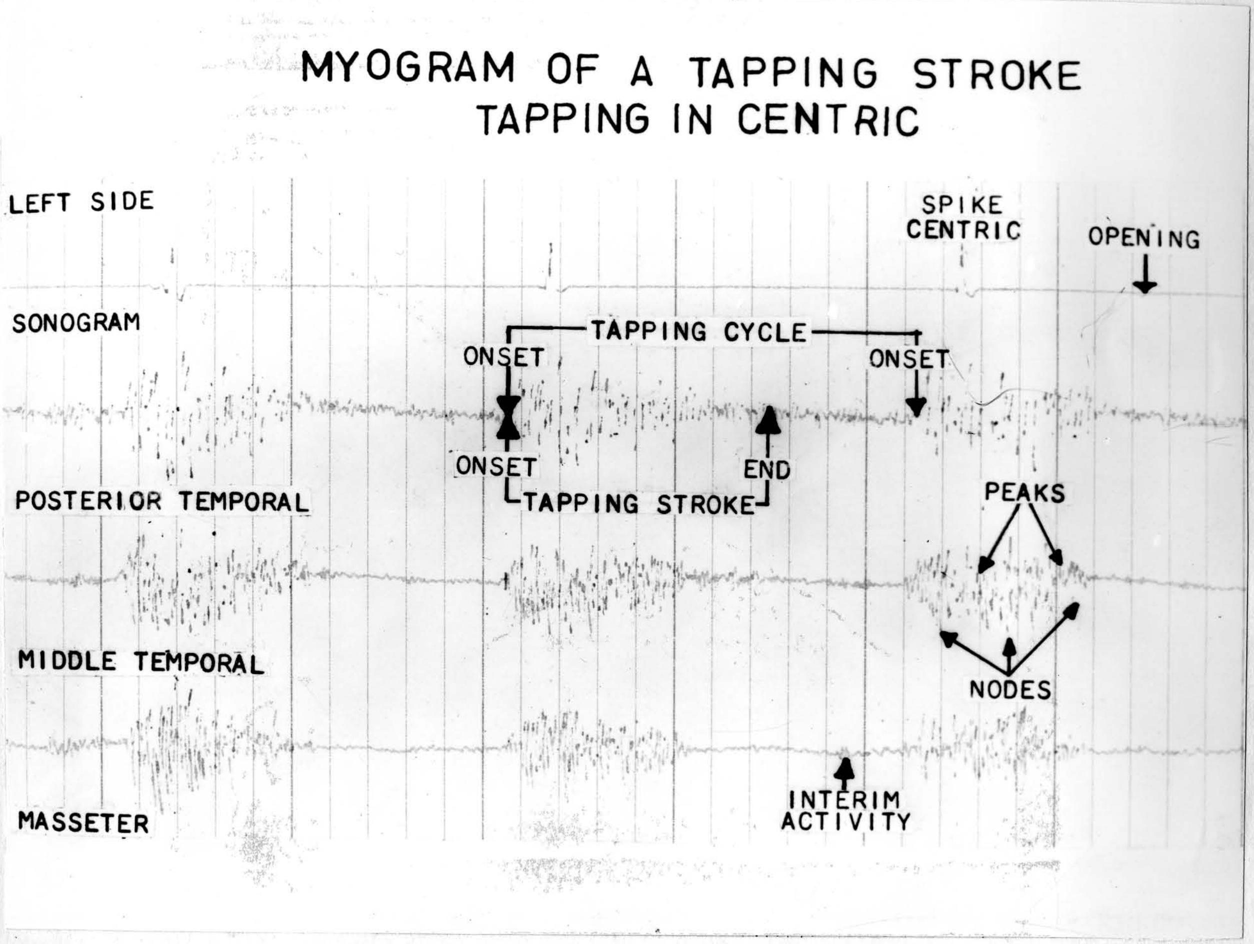

MYOGRAM OF A TAPPING STROKE
TAPPING IN CENTRIC
LEFT SIDE
SPIKE
CENTRIC
OPENING
SONOGRAM
TAPPING CYCLE
ONSET
ONSET
ONSET
END
TAPPING STROKE
POSTERIOR TEMPORAL
PEAKS
MIDDLE TEMPORAL
NODES
INTERIM
ACTIVITY
MASSETER

FIGURE 12

K. Defining the Characteristics of the Myograms

The myograms contain two basic dimensions: amplitude and time. Relative amplitudes were studied along with the rates of change of amplitude with respect to time. Amplitudes were either sustained high, low, or zero. The absolute amplitude was not measured because of the numerous factors affecting its variability. A "peak" is defined as high amplitudes of short duration, preceded and followed by rapid rates of change in amplitude. "Noding" is defined as brief low or zero amplitude, bordered by rapid decrease and rapid increase in amplitude.

The chewing cycle was considered to be that period of time from the beginning of one isometric contraction of the muscle to the beginning of the next isometric contraction of that particular muscle as determined from the electromyographic recording. The chewing stroke was that portion of the chewing cycle which began with the onset of electrical activity and terminated with the end of isometric contraction.

The length of duration of the muscular activity of each chewing stroke was studied as a whole and also divided into two components: onset of activity and end of activity. At the onset of activity, the rate of increase of amplitude, and at the end of activity, the rate of decrease of amplitude, were indications of the manner in which the patient chewed. The form of the electromyogram was analyzed for frequency of bursts of activity. To demonstrate graphically the form of the myogram, lines were drawn on the myogram connecting spikes of minimum amplitude with spikes of maximum amplitude (Figure 13). The activity between the myograms of successive chewing cycles, termed "interim activity", was also identified and studied.

L. Evaluation of the Electromyographic Data

To gain a knowledge of the behavior of the temporal and masseter muscles within the experimental conditions, and to recognize the occurrence of any trends in their behavior during orthodontic treatment, the myograms from Experiment VIII were analyzed and compared to previous studies as follows:

Method I Listing and Evaluating the Characteristics for Each Individual Subject

Method II Analyzing the Initiation of the Chewing Activity

Method III Measuring the Duration of the Chewing Stroke

Method IV Analyzing the Number of Bursts Per Chewing Stroke

MYOGRAM OF A CHEWING STROKE
CHEWING A COUGH DROP

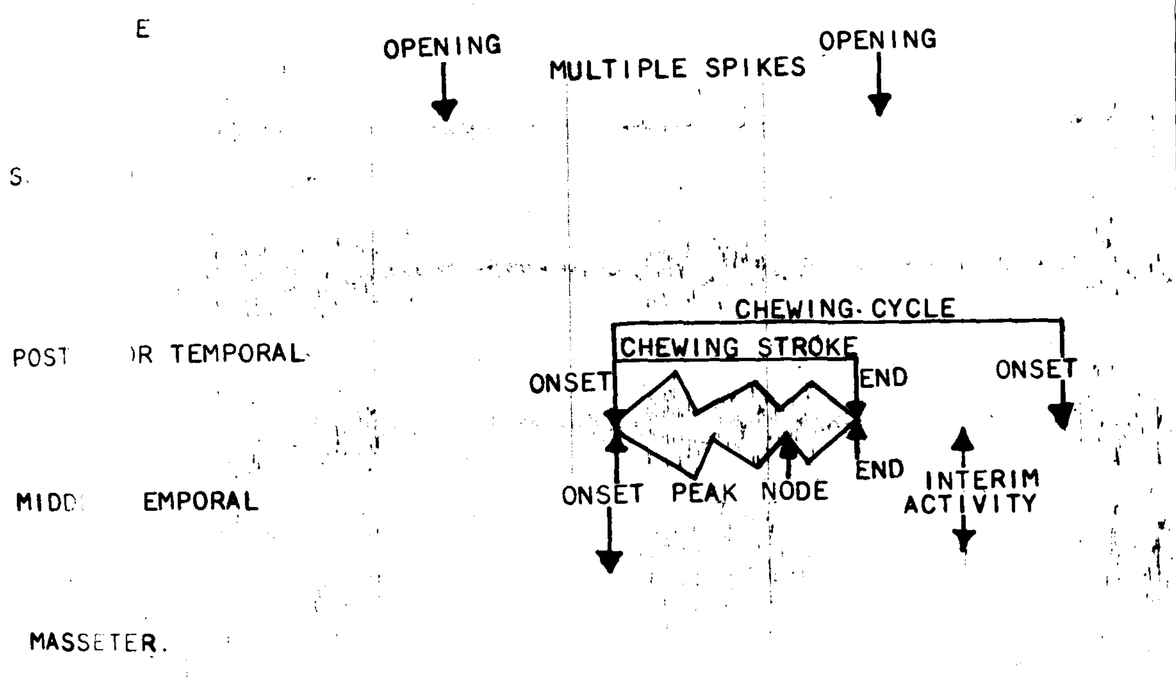


FIGURE 13

Method I Listing and Evaluating the Characteristics of the Myograms

The following characteristics were grouped and grossly evaluated: bursts, amplitude, duration, noding, sustained low amplitude, rate of onset, rate of ending, and the interim activity (Part B of the "FINDINGS").

The rating scale used for evaluating all of the characteristics other than bursts, which were tabulated as counts is as follows:

xxx	Maximum
xx	Medium
x	Minimum

Method II Analyzing the Initiation of the Chewing Activity

The onset of electromyographical activity for each of the muscles in each of the first three chewing cycles of every exercise was marked on the myogram. A straight edge was then held at right angles to the border of the paper so that it passed through the ink recordings of all three muscles. The straight edge was then moved along the myogram until it contacted the mark of the first muscle (or muscles) to begin electrical activity, which was then listed in chart form. The data from this experiment and the data from the previous experiments were made into a chart in order to compare the frequency of occurrence of each muscle (or muscles) which initiated the chewing cycle in all experiments. The data were then plotted as a graph (Part C of the "FINDINGS") to illustrate the change in behavior of the muscles for all experiments to date.

Method III Measuring the Duration of the Chewing Stroke

The lengths of the durations of the chewing strokes were expressed as percentages of the chewing cycles rather than as a direct measurement because the subjects did not chew at a uniform rate. In recording the electromyograms it was necessary to instruct some subjects to chew the cough drops more slowly than their usual speed because the chewing cycles were indistinguishable at that faster rate. Expressing the length of the duration of the chewing stroke as a percentage of the chewing cycle compensated for this change.

The lengths of each of the first three chewing cycles and the chewing strokes within these chewing cycles were measured. The length of each stroke was then calculated as a percentage of the chewing cycle. The resulting percentages were grouped into percentage intervals. These intervals, termed class intervals by the previous investigators, Fleming and Zylinski (1961), represented a spread of ten percent and were a convenient method of dividing the percentages into ten groups, ranging from zero to one hundred percent. These groups were then used in making a histogram for each experiment in this investigation.

The data were also subjected to the Chi Square Test and judged for significance. The Null Hypothesis for this test is that the data are all drawn from one parent distribution; that they are thus statistically alike; and that there would be no significant difference in the distribution of the lengths of the duration of the chewing stroke (as expressed as a percentage of the chewing cycle) during the stages of orthodontic treatment that distinguish these eight experiments. Independent comparisons were also made between Experiment VIII and Experiment I, and between Experiment VIII and Experiment VII, using the Chi Square Test for significance.

Method IV Analyzing the Number of Bursts per Chewing Stroke

The number of bursts in each of the first three chewing strokes was counted. A random sample of these was taken from each subject and analyzed, using the Analysis of Variance Test for significant differences. Since counts do not follow the normal distribution, they are not amenable to the use of the Analysis of Variance Test without being transformed. The transformation used in this case was the square root of the observations, plus one.

M. Statistical Discipline

This overall study was basically a qualitative study and the analysis of the data was done on a relative basis. In the first experiment Widen (1960) considered each subject as a separate experimental unit because the population was heterogeneous, due to the various malocclusions presented, and because there were no prior data for comparison. As successive experiments were completed, enough data were accumulated to permit developing meaningful, statistical analyses.

Method III and Method IV were analyzed by statistical methods.

In Method III, the Chi Square Test for significance was used to determine whether there was a statistically significant difference between experiments in the distribution of the lengths of the chewing stroke when expressed as a percentage of the chewing cycle.

In Method IV, the Analysis of Variance was used to compare inhibition (as shown by the number of bursts in a chewing stroke) between patients without appliances and those with appliances.

CHAPTER III

FINDINGS

A. Introduction

The data were obtained from the electromyograms for the first three chewing cycles of each exercise performed by the sixteen people in the investigation. Findings from this experiment were compared with those from the previous studies (Experiment I through Experiment VII) in four ways, described in the chapter on "METHODS AND MATERIALS" as follows:

Method I — Listing and Evaluating the Characteristics of the Myograms of the Individuals

Method II — Analyzing the Initiation of the Chewing Activity by the Various Muscles

Method III — Measuring the Duration of the Chewing Stroke as a Percentage of the Chewing Cycle

Method IV — Analyzing the Number of Bursts in a Chewing Stroke

This chapter has been divided into four parts to consider the data from each of the four methods of the investigation.

B. Listing and Evaluating the Characteristics of the Myograms of the Individuals

The object of this part is to observe the changes in the myograms of each individual with respect to the phase of orthodontic treatment. The type of malocclusion (according to Angle's Classification of malocclusion) was recorded along with photographs of the treatment stage at the time of the electromyographic recordings, and photographs of the plaster casts of the subjects before orthodontic treatment was begun. The subjects in the group studied included three cases of neutrocclusion (Class I malocclusion) and thirteen cases of distocclusion (Class II malocclusion). An explanation of treatment mechanics used and the intraoral photographs of each subject will show the particular phase of treatment, as well as the progress of each patient at the time the electromyogram was taken.

The following characteristics of the myogram for each subject recorded for Experiments I through Experiments VIII were listed in chart form and evaluated: number of bursts, amplitude, duration, noding, sustained low amplitude, rate of onset, rate of ending, interim activity, and the initiating of the chewing activity. Except for the counting of the number of bursts and the recording of which muscle or muscle groups initiated the chewing cycle, all the characteristics were rated on a qualitative basis as explained in the section on "METHODS AND MATERIALS" (page 53).

Subject #1 (L.C.)

Male

Age, sixteen years

Angle Classification of Malocclusion, Class I (Figure 14)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 15): the active appliance had been removed and the patient was using a rubber finishing appliance for functional retention of the teeth.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 16):

BURSTS increased from Experiment I through Experiment V, leveled off at Experiment VI, and began a decrease with Experiment VII, which continued through Experiment VIII.

AMPLITUDE was moderate in all experiments except in Experiment III and VIII where it was maximum.

DURATION was minimum in Experiments I and VIII and was moderate in the other experiments.

SUSTAINED LOW AMPLITUDE occurred only in Experiments V and VI.

FIGURE 14

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #1

BEFORE ORTHODONTIC TREATMENT

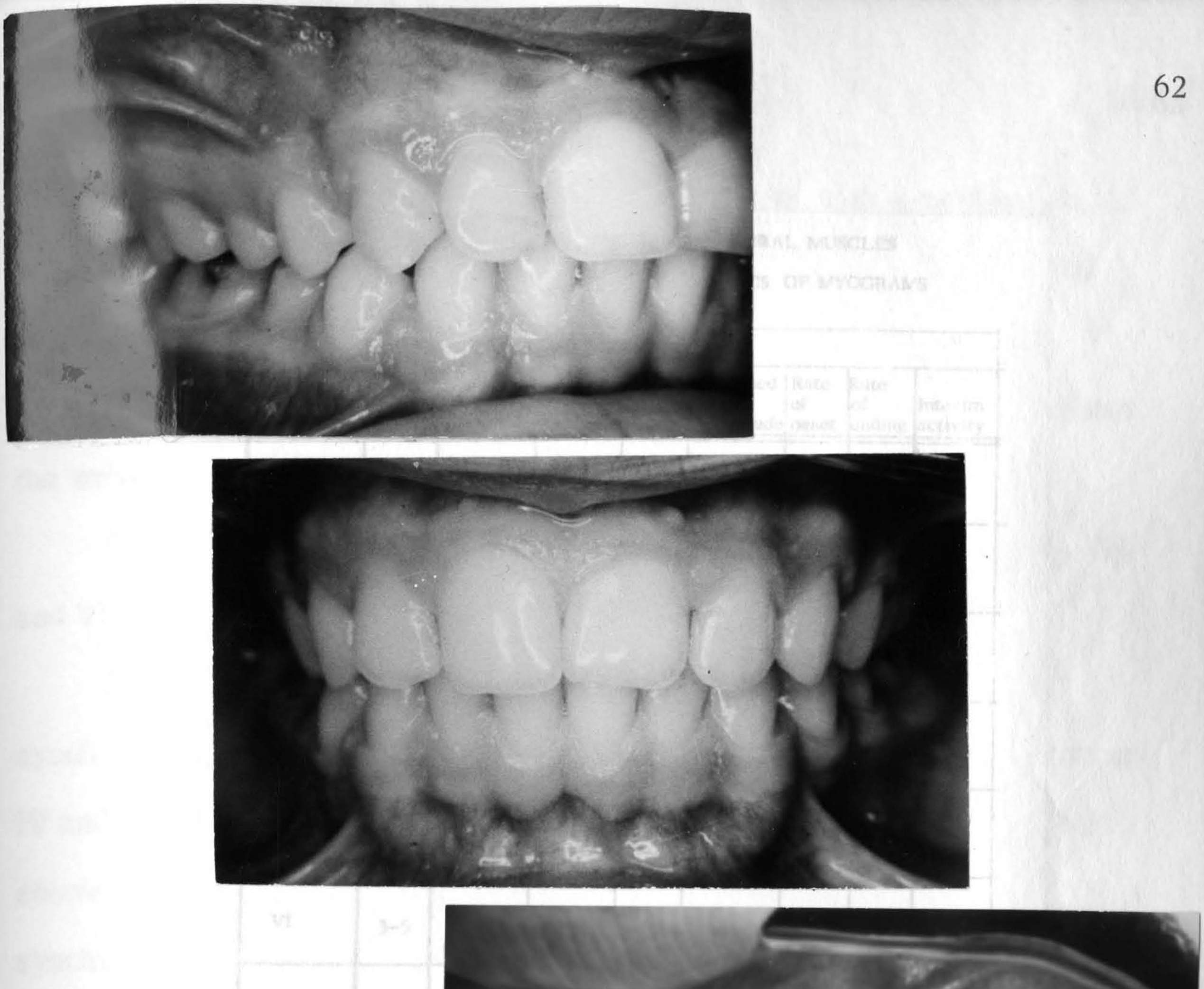


FIGURE 15

INTRAORAL PHOTOGRAPHS OF SUBJECT #1

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 1 L. C.								
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1-2	xx	x	x	0	xxx	xxx	x
II	1-3	xx	xx	xx	0	xxx	xx	xx
III	2-5	xxx	xx	xx	0	xxx	xxx	xx
IV	2-4	xx	x	xx	0	xxx	xxx	x
V	3-5	xx	xx	xx	x	x	xx	x
VI	3-5	xx	xx	xx	x	x	xx	x
VII	1-4	xxx	xx	xx	0	xx	xx	xx
VIII	1-4	xx	x	x	0	xx	xx	x

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 16

RATE OF ONSET was maximum in the first four experiments, minimum in Experiments V and VI, and moderate in Experiments VII and VIII.

RATE OF ENDING varied from maximum to moderate throughout the study.

INTERIM ACTIVITY was minimum except for Experiments II, III, and VII where it was moderate.

INITIATION OF CHEWING ACTIVITY (Figure 17) shows that synchronous initiation decreases from Experiment I through Experiment IV and then remains constant through Experiment VI. Experiment VII shows a sharp increase in synchrony and Experiment VIII shows synchronous initiation of the chewing activity for all exercises studied.

SUMMARY:

Concurrent with the removal of the active appliance in Experiment VII and continuing through Experiment VIII, there was an absence of sustained low amplitude, an increase in the synchronous initiation of the chewing activity, and a decrease in the amount of inhibition (as shown by the decrease in the number of bursts).

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 1. L. C.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	1	3	2	5	5	4	1	0
Masseter and middle temporal first	0	0	0	1	0	0	0	0
Masseter and posterior temporal first	0	0	1	0	0	0	0	0
Middle and posterior temporal first	0	0	2	0	0	2	0	0
Middle temporal first	0	0	0	0	0	0	0	0
Posterior temporal first	1	2	0	0	1	0	0	0
All together (Synchrony)	10	7	7	6	6	6	11	12
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 17

Subject #2 (E.G.)

Female

Age, thirteen years

Angle Classification of Malocclusion, Class II, Division 1 (Figure 18)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 19): the active appliance had been removed and the patient was using a rubber finishing appliance for functional retention of the teeth.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 20):

BURSTS were similar for the first four experiments, increased sharply during Experiments V and VI, decreased beginning with Experiment VII, and continued in this direction through Experiment VIII.

AMPLITUDE was moderate in the first four experiments. Beginning with Experiment V and continuing through Experiment VIII, amplitude was maximum.

DURATION was maximum in all experiments except in Experiments IV and VIII where it was moderate.

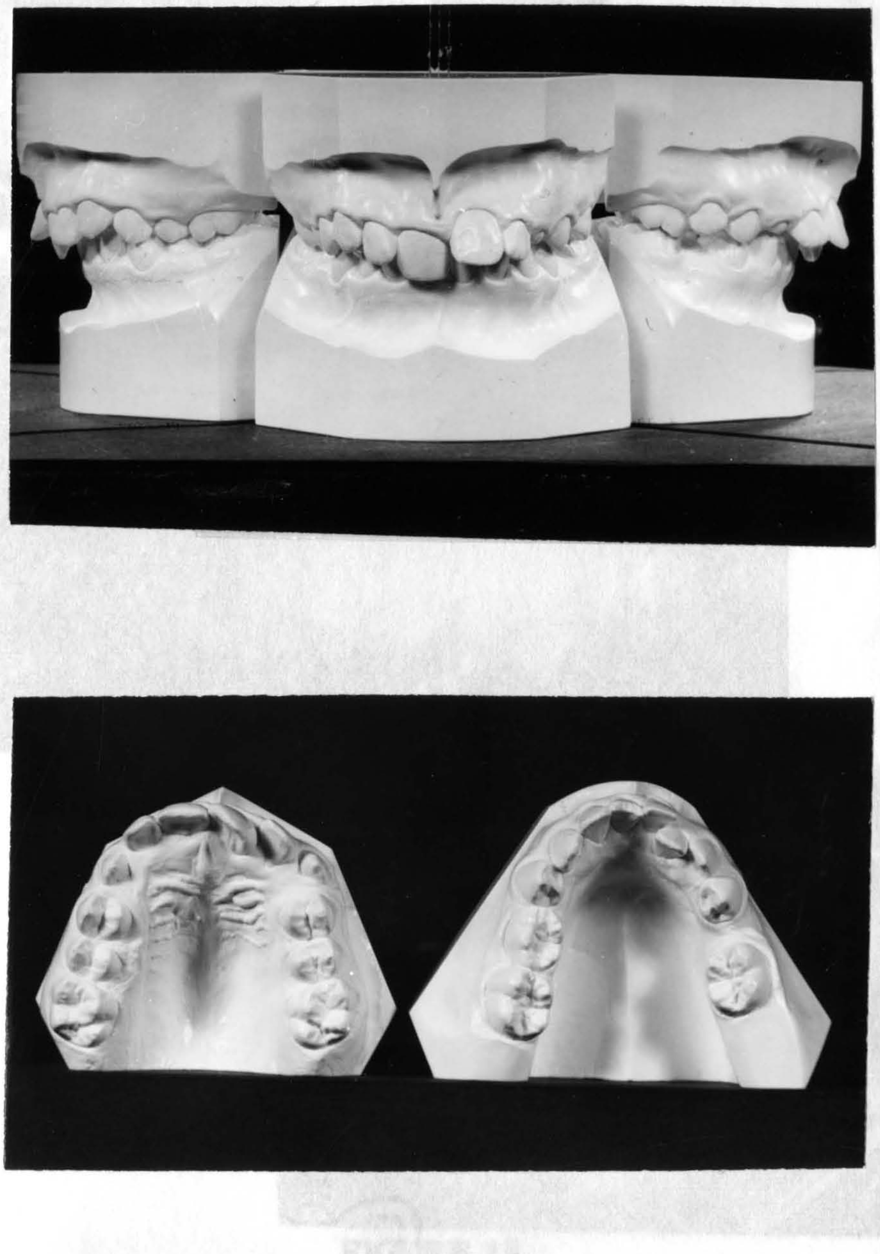


FIGURE 18

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #2

BEFORE ORTHODONTIC TREATMENT

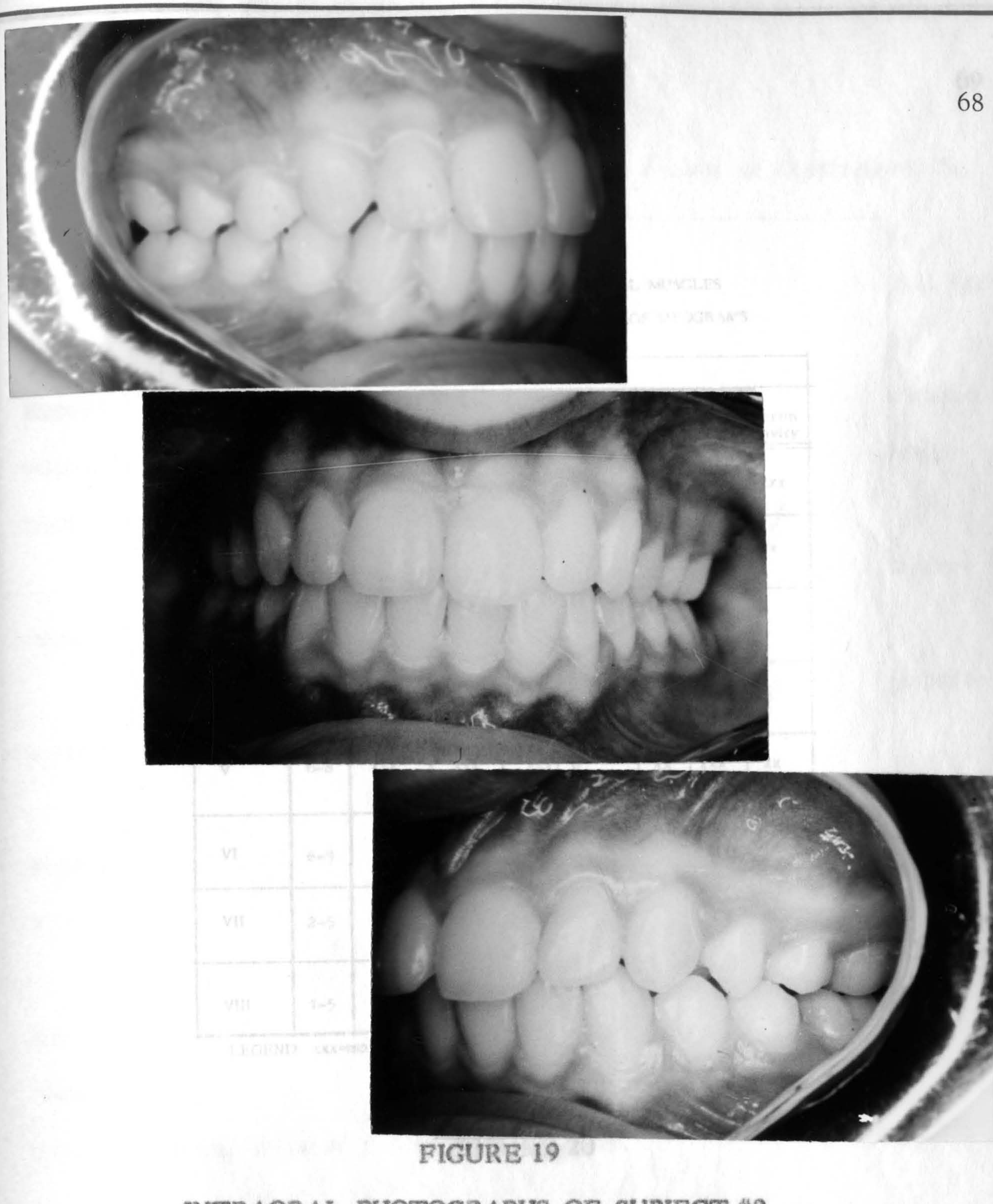


FIGURE 19

INTRAORAL PHOTOGRAPHS OF SUBJECT #2

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 2 E. G.								
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	4-6	XX	XXX	XXX	O	XX	XX	XXX
II	4-6	XX	XXX	XX	X	XX	XX	XX
III	4-6	XX	XXX	XXX	X	XX	XX	X
IV	4-5	XX	XX	XXX	O X-MASS. ONLY	XX	XX	X
V	6-8	XXX	XXX	XXX	O XX- MASS. ONLY	XX	XXX	XX
VI	6-9	XXX	XXX	XXX	XXX- MASS. ONLY O	XX	XX	XX
VII	2-5	XXX	XX-XXX	XX	XX- [illegible]	XX	XX	X
VIII	1-5	XXX	XX	XX	O	X	XX	O

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 20

NODING was maximum in all experiments except in Experiments II, VII, and VIII. In these experiments there was moderate noding.

SUSTAINED LOW AMPLITUDE was zero in the first Experiment, but increased in Experiments II, III, and IV where it was minimum. In Experiment V the masseters showed a moderate amount and this became maximum in Experiment VI. In Experiment VII the posterior temporals show sustained low amplitude; but by Experiment VIII there is none.

RATE OF ONSET was moderate in all experiments except Experiment VIII where it was minimum.

RATE OF ENDING was moderate in all experiments except Experiment V where it was maximum.

INTERIM ACTIVITY was maximum in Experiment I and went to zero (no obvious change) in Experiment VIII. In the intervening experiments it was moderate in II, V, and VI; minimum in Experiments III, IV, and VII.

INITIATION OF CHEWING ACTIVITY (Figure 21) shows a decline in the number of times the masseter initiates the chewing stroke as treatment progresses; and an increase in the number of times there is a synchronous initiation of the chewing activity.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 2. E.G.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	4	4	6	4	1	2	0	0
Masseter and middle temporal first	1	0	2	0	0	0	0	0
Masseter and posterior temporal first	1	0	0	0	0	0	1	0
Middle and posterior temporal first	0	2	1	0	2	3	0	0
Middle temporal first	0	1	0	0	2	5	1	0
Posterior temporal first	0	1	0	0	0	0	2	0
All together (Synchrony)	6	4	3	8	7	2	8	12
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 21

SUMMARY:

Concurrent with the removal of the active appliance in Experiment VII and continuing through Experiment VIII, there was an increase in the synchronous initiation of the chewing activity and a decrease in the amount of inhibition (as shown by the decrease in the number of bursts). In Experiment VIII there is a decrease in sustained low amplitude and in interim activity.

Subject #3 (R. H.)

Male

Age, thirteen years

Angle Classification of Malocclusion, Class II Division 1 (Figure 22)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 23): a space was being created distal to the right canine so that the midline of the maxillary arch could be aligned with the midline of the mandibular arch. The appliance consisted of a straight (horizontal) archwire with attachments (coil springs and sliding hooks) in the maxilla, a consolidation archwire with horizontal hooks distal to the lower lateral incisors in the mandible, and a heavy quarter-inch, Class II elastic on the right side only in order to activate the sliding hook and closed coil. High pull headgear was used a minimum of fourteen hours each day.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VII (Figure 24):

BURSTS increased in Experiments III, IV, V, and VI approximately twice the number of bursts recorded in Experiments I and II. Experiments

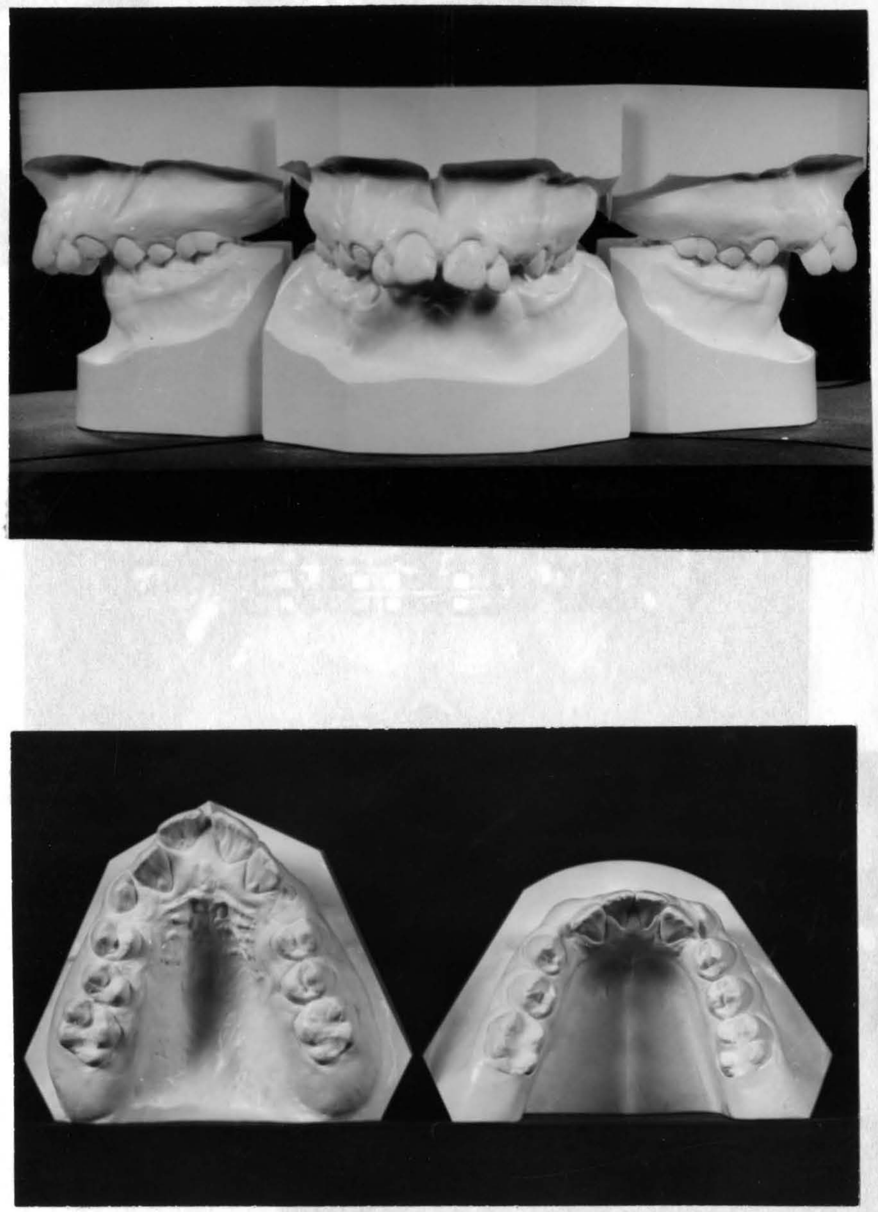


FIGURE 22

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #3

BEFORE ORTHODONTIC TREATMENT

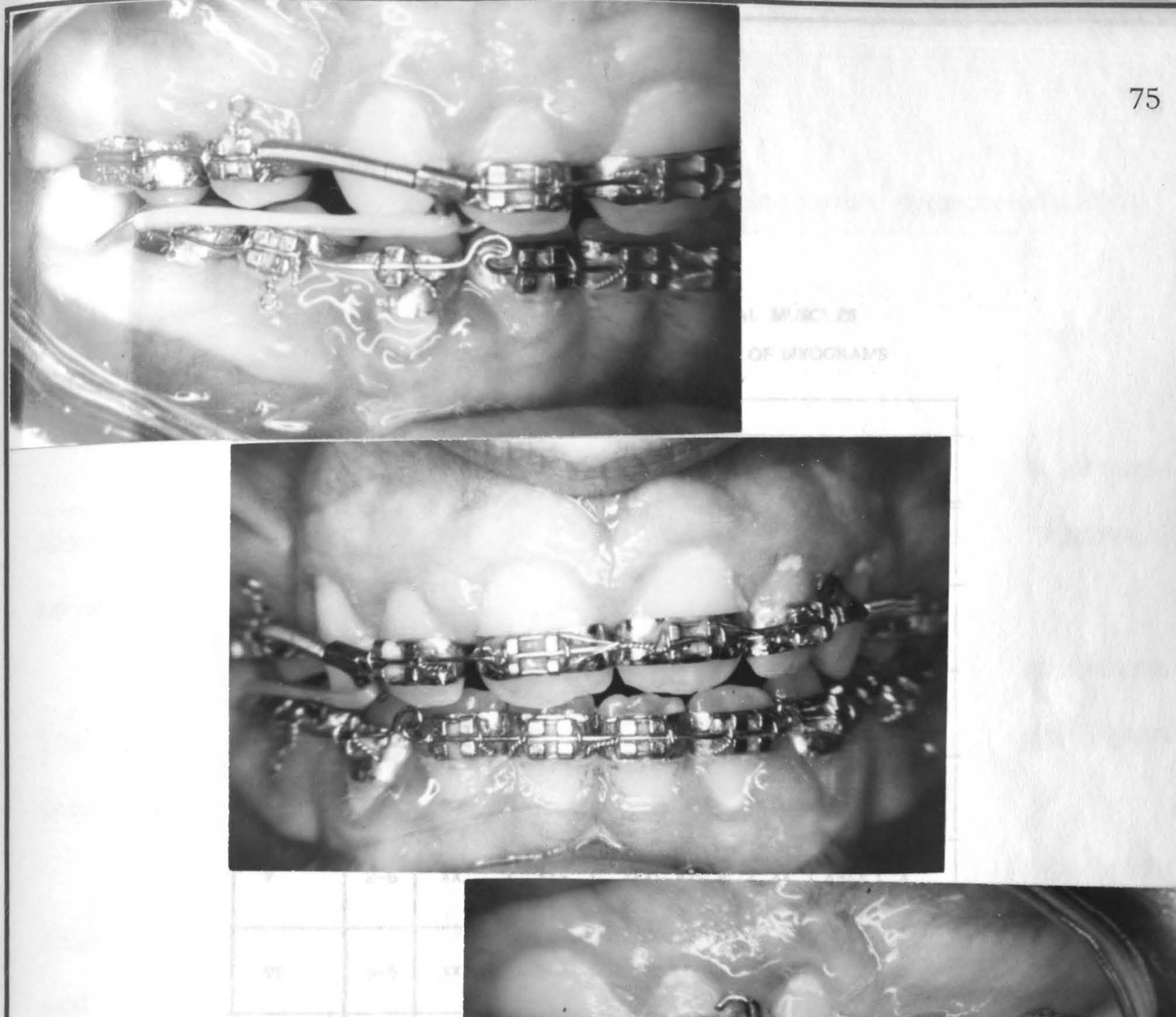


FIGURE 23

INTRAORAL PHOTOGRAPHS OF SUBJECT #3

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 3 R. H.								
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1-3	XX-RT. X-LT.	X	X	LT. MASS.	XX	XX	XX
II	1-3	XX	X	X-XX	RT. & LT. MASS.	X	XX	X
III	3-6	XXX	XX	XX	LT. MASS.	XX	XX	XX
IV	3-6	XX	XX	XX	RT. & LT. MASS.	XX	XX	XX
V	2-6	XX	XX-XXX	XXX	RT. & LT. MASS.	XX	X-XX	X
VI	3-5	XX	XX-XXX	XXX	RT. & LT. MASS.	XX	XX	X
VII	1-6	XXX	XXX	X-XXX	0	XX	XX	X
VIII	1-4	XX-XXX	XX	X	0	XX	XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 24

VII and VIII show a decrease in number of bursts, with Experiment VIII approximating the same number as Experiment I.

AMPLITUDE was moderate except for Experiments III, VII, and VIII where it was maximum.

DURATION showed a progressive increase from minimum in Experiment I to maximum in Experiment VII. Experiment VIII shows a decrease to moderate.

NODING shows a progressive increase from minimum in Experiment I to maximum in Experiment V. The maximum is sustained through Experiment VII and drops back to minimum in Experiment VIII.

SUSTAINED LOW AMPLITUDE was recorded in the masseters from Experiment I through Experiment VI. It drops to zero in Experiment VII and remains there in Experiment VIII.

RATE OF ONSET was moderate throughout all the experiments.

RATE OF ENDING was moderate throughout all the experiments.

INTERIM ACTIVITY was moderate in Experiments I, III, and IV, and minimum in the remaining Experiments.

INITIATION OF CHEWING ACTIVITY (Figure 25) showed a decline in the number of times the masseter initiated the chewing stroke, but

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 3 R.H.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	3	2	3	2	0	0	2	0
Masseter and middle temporal first	0	1	1	1	0	0	0	0
Masseter and posterior temporal first	0	0	0	0	0	1	0	1
Middle and posterior temporal first	1	0	3	0	4	4	1	3
Middle temporal first	0	1	0	0	1	1	0	0
Posterior temporal first	3	0	0	8	2	2	0	5
All together (Synchrony)	5	8	5	1	5	4	9	3
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 25

indicated no definite trend regarding the synchronous initiating of the chewing activity.

SUMMARY:

As treatment progressed, there was a decrease in the number of bursts, noding, sustained low amplitude and interim activity. There was a decrease in the number of times the masseter initiated the chewing cycle, but no conclusive trend in the synchronous initiation of the chewing activity.

Subject #4 (M.K.)

Female

Age, thirteen years

Angle Classification of Malocclusion, Class II, Division 1, subdivision (Figure 26)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 27): leveling of the maxillary occlusal plane, consolidation of the maxillary anterior teeth, and correction of the midline. The appliance consisted of a maxillary leveling arch, and lower ideal arch. There were Class II heavy quarter-inch elastics hooked over the horizontal loops to facilitate consolidation and midline correction. High-pull headgear was also used at this stage.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VII (Figure 28):

BURSTS increased in Experiment III, IV, and V over that of Experiment I and II. Experiment VI shows a return to the same level of bursts as in the first experiment, but there is a sharp increase again in Experiment VII and VIII.

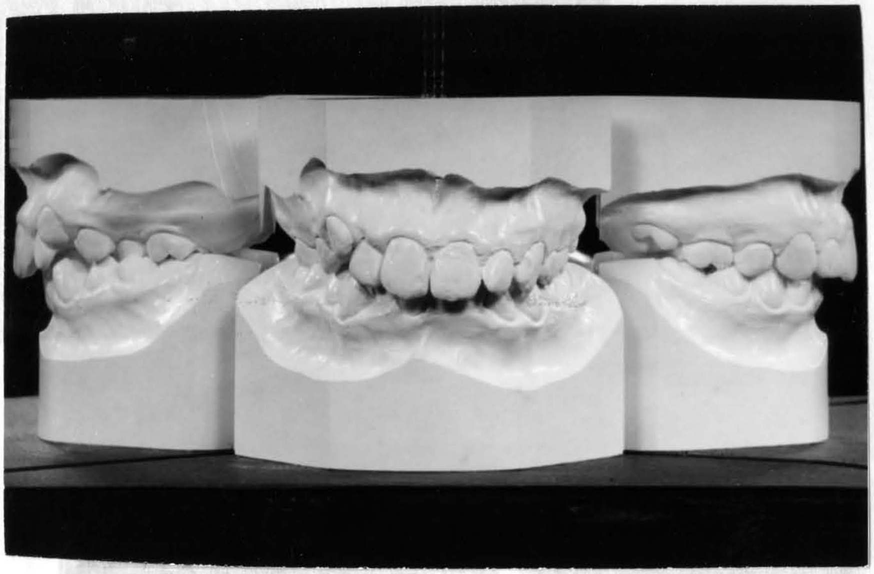


FIGURE 26

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #4

BEFORE ORTHODONTIC TREATMENT

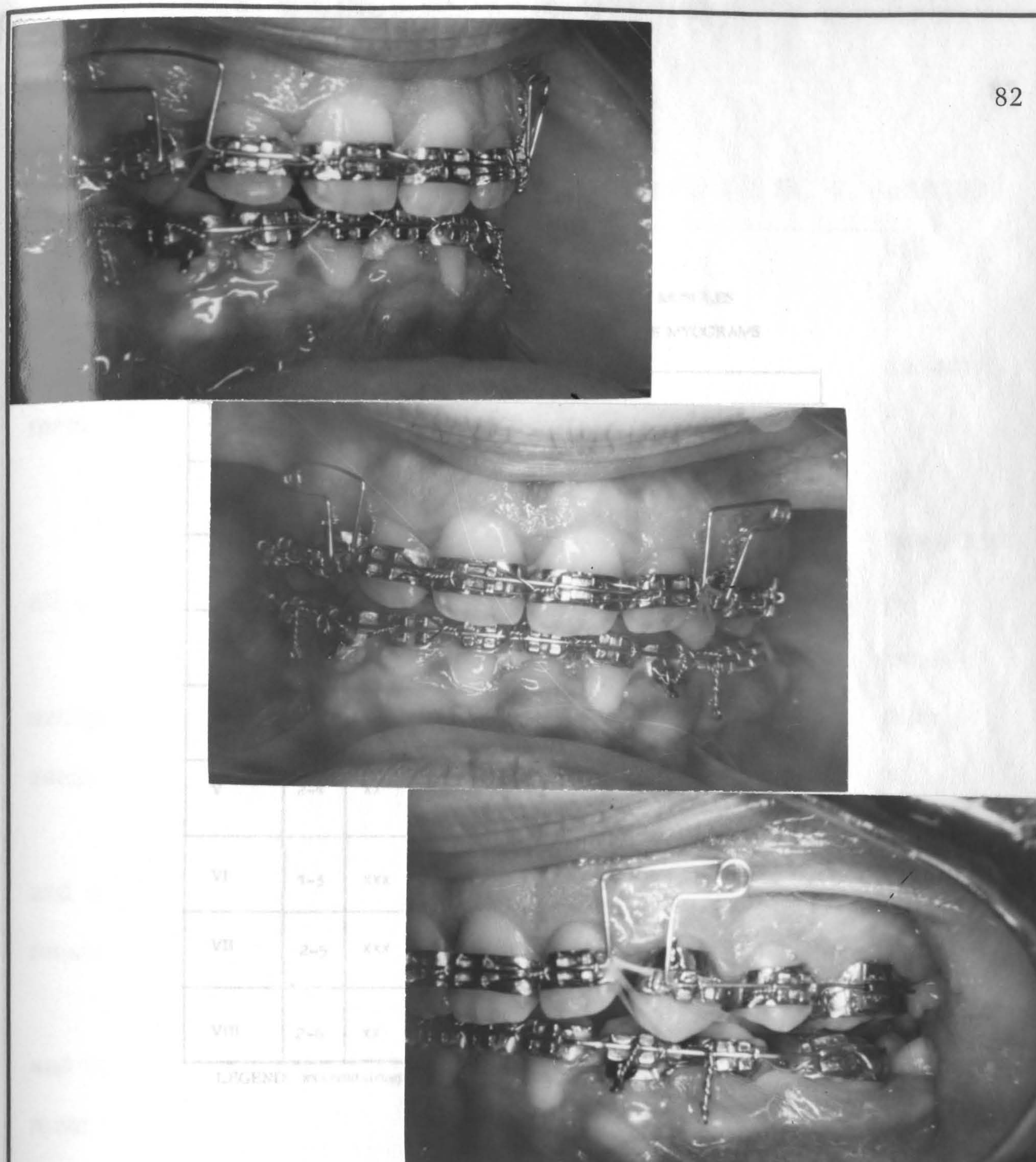


FIGURE 27

INTRAORAL PHOTOGRAPHS OF SUBJECT #4

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 4 [illegible]								
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1-3	XX	X	XX	RT. MASS. & POST. TEMP. X	XX	XX	X
II	1-3	X	X	XX	XX	XX	XX	XX
III	3-5	XX	X	XX	RT. MASS. & POST. TEMP. XX	XX	XX	X
IV	2-4	XX	XX	XX	XX- RT. MASS.	XX	XX	MASS. & PT. TEMP. X
V	2-4	XX	XX-XXX	XX	X- RT. MASS.	X-XX	XX	X
VI	1-3	XXX	XX	X	XX- MASS.	XX-XXX	XX-XXX	X
VII	2-5	XXX	XX	XX	LT. POST. & RT. MID. & POST. TEMP. X	X-XX	X-XX	0
VIII	2-6	XX	XX	X	0	X-XX	X-XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 28

AMPLITUDE was moderate in Experiments I, III, IV, V, and VIII; maximum in Experiments VI and VII; and minimum in Experiment II.

DURATION was minimum in Experiment I, II, III; increased to moderate in Experiment IV; and remained at that level through Experiment VIII.

NODING was moderate in all experiments except VI and VIII.

SUSTAINED LOW AMPLITUDE was moderate in the masseters for all Experiments, except in Experiment VIII where there was none.

RATE OF ONSET was moderate throughout all the experiments except in Experiments V, VII, and VIII with a moderate to minimum range and in Experiment VI, with a moderate to maximum range.

RATE OF ENDING was moderate through the first five experiments and varied in Experiment VI from moderate to maximum and in Experiments VII and VIII from moderate to minimum.

INTERIM ACTIVITY was minimum in Experiments I, III, IV, V, VI, and VIII; moderate in Experiment II; and with no obvious change in Experiment VII.

INITIATION OF CHEWING ACTIVITY (Figure 29) showed a decrease in the number of times the masseter initiated the chewing stroke, and

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 4. M. K.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	6	7	4	8	1	0	1	1
Masseter and middle temporal first	1	0	0	0	0	1	1	3
Masseter and posterior temporal first	0	0	0	0	0	0	0	0
Middle and posterior temporal first	0	2	0	1	2	3	1	0
Middle temporal first	0	1	1	0	1	0	0	0
Posterior temporal first	0	0	0	1	0	0	2	0
All together (Synchrony)	5	2	7	2	8	8	7	8
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 29

a slight increase in the number of times there was a synchronous initiation of chewing activity.

SUMMARY:

There is a decrease in the number of times the masseter initiated the chewing stroke, a slight increase in the number of times there was synchronous initiation of the chewing activity, and there is also a disappearance of sustained low ampltude.

Subject #5 (M.M.)

Male

Age, thirteen years

Angle Classification of Malocclusion, Class II, Division 1 (Figure 30)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 31): opening of the occlusal-vertical dimension; leveling of the occlusal plane; and correcting the lingual cross bite of the mandibular arch. The appliance consisted of a bite plane in maxillary arch (no archwire) and a leveling archwire in the mandible. Quarter-inch heavy elastics were used in correcting the cross bite.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 32):

BURSTS remained fairly constant from Experiment I through VI, but decreased in Experiment VII and VIII.

AMPLITUDE was minimum from Experiment I through IV, increased to moderate in Experiments V and VI, increased to maximum in Experiment VII, and then decreased to moderate in Experiment VIII.

DURATION remained minimum from Experiment I through IV, was

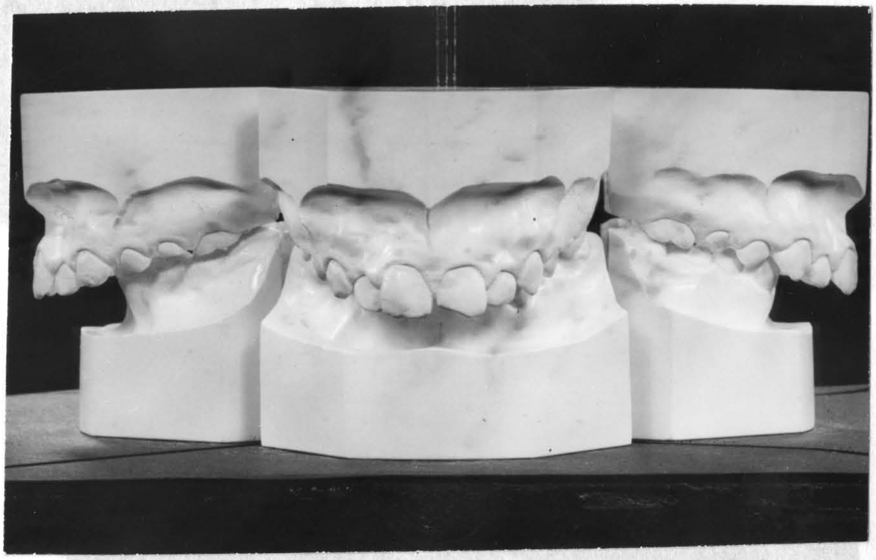


FIGURE 30

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #5

BEFORE ORTHODONTIC TREATMENT

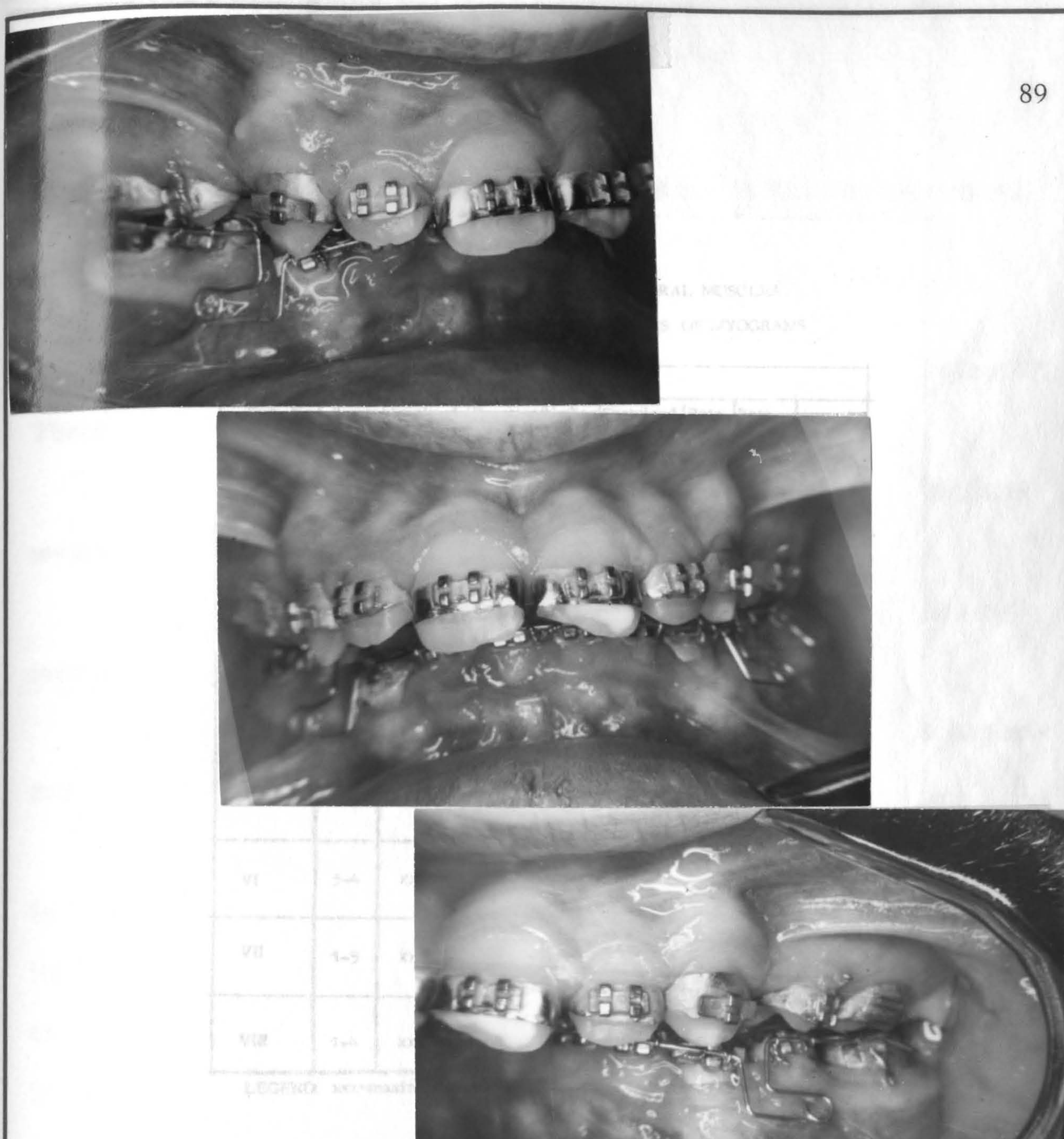


FIGURE 31

INTRAORAL PHOTOGRAPHS OF SUBJECT #5

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT	NUMBER: 5 [illegible]. M.							
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-3	X	X	XX	X- MASS.	XX	XX	X
II	2-3	X	X	XX	X- MASS.	XX	XX	X
III	3-4	X	X	XX	X- MASS.	XX	XX	X
IV	2-3	X	X	XX	XX- MASS.	XX	XX	X
V	2-3	XX	XX	XX	X- MASS.	X	XX	X
VI	3-4	XX	XX	XX	X MASS.	X	XX	XX
VII	1-5	XXX	XX-XXX	XX	MASS. RT. POST. TEMP. X	XX	XX	XX
VIII	1-4	XX	XX	XX	0	XX	XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 32

moderate in Experiments V and VI, was maximum in VII, and decreased to moderate in Experiment VIII.

NODING was moderate throughout all experiments.

SUSTAINED LOW AMPLITUDE was minimum through Experiment VII. There was no sustained low amplitude in Experiment VIII.

RATE OF ONSET was moderate in all experiments except Experiments V and VI.

RATE OF ENDING remained moderate throughout all the Experiments.

INTERIM ACTIVITY was minimum in all experiments except Experiments VI and VII.

INITIATION OF CHEWING ACTIVITY (Figure 33) showed a decrease in the number of times the masseter initiated the chewing activity; an increase of the middle and posterior temporal through Experiment V; and a decrease in the succeeding experiments. Although there was an increase in Experiment VIII over Experiment I in the number of times synchronous initiation of the chewing activity occurred, there was a decrease from Experiment VII to Experiment VIII.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 5. M.M.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	6	7	3	2	0	0	0	2
Masseter and middle temporal first	0	1	0	0	0	0	0	1
Masseter and posterior temporal first	0	0	0	1	0	0	1	0
Middle and posterior temporal first	0	0	3	5	10	3	2	2
Middle temporal first	0	0	0	0	0	0	0	0
Posterior temporal first	1	0	3	1	1	0	0	0
All together (Synchrony)	5	4	3	3	1	9	9	7
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 33

SUMMARY:

As treatment progressed, there was a decrease in the amount of inhibition (as shown by a decrease in the number of bursts); the elimination of sustained low amplitude; a decrease in the number of times the masseter initiated the chewing cycle; and an erratic but general increase in the number of times there was a synchronous initiation of the chewing cycle.

Subject #6 (K.M.)

Female

Age, fifteen years

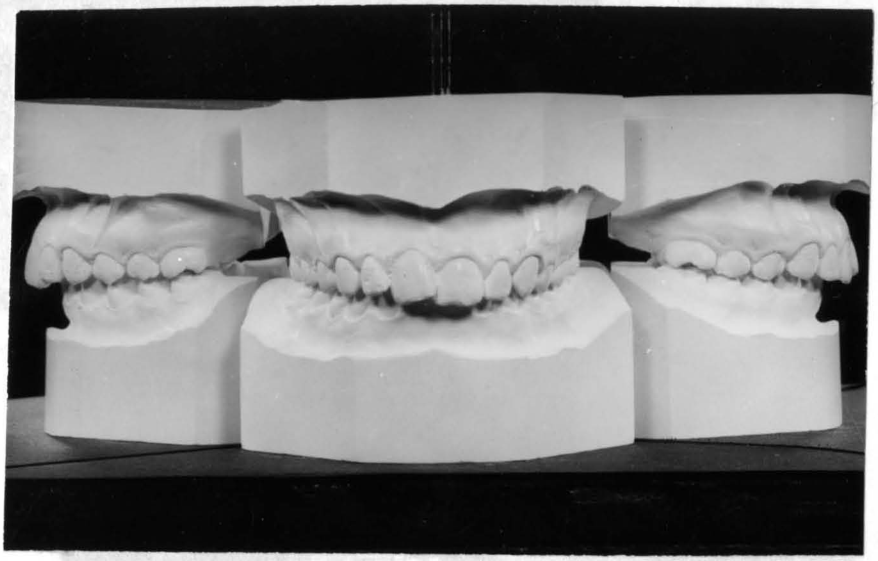
Angle Classification of Malocclusion, Class II, Division 1 (Figure 34)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 35): correcting of the Class II molar relation. The appliance consisted of a straight (horizontal) archwire with attachments (sliding hooks and coil springs) in the maxilla. The mandibular archwire was a straight (horizontal) ideal archwire without attachments. Quarter-inch light elastics were used buccally and lingually from the mandibular molar.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 36):

BURSTS were very high from the first experiment through the sixth experiment. Experiments VII and VIII show a very sharp decline in the number of bursts.

AMPLITUDE was moderate in Experiments I, II, III, and V; the remaining Experiments were maximum.



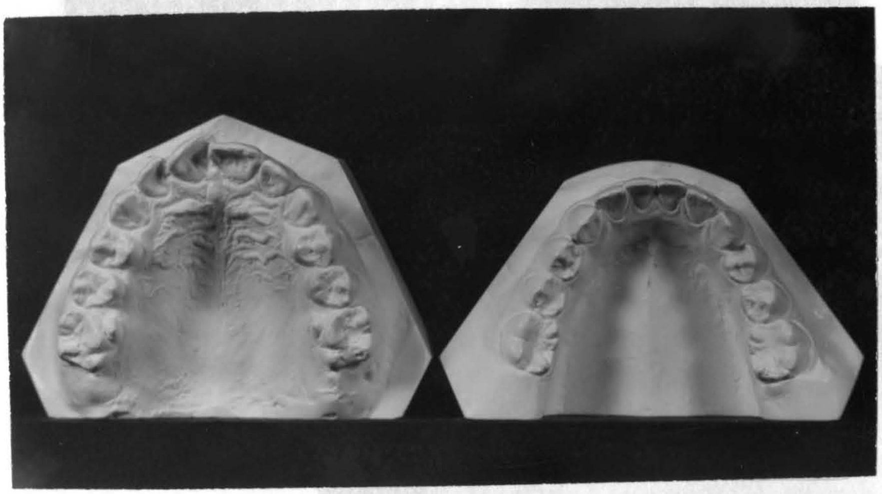


FIGURE 34

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #6

BEFORE ORTHODONTIC TREATMENT

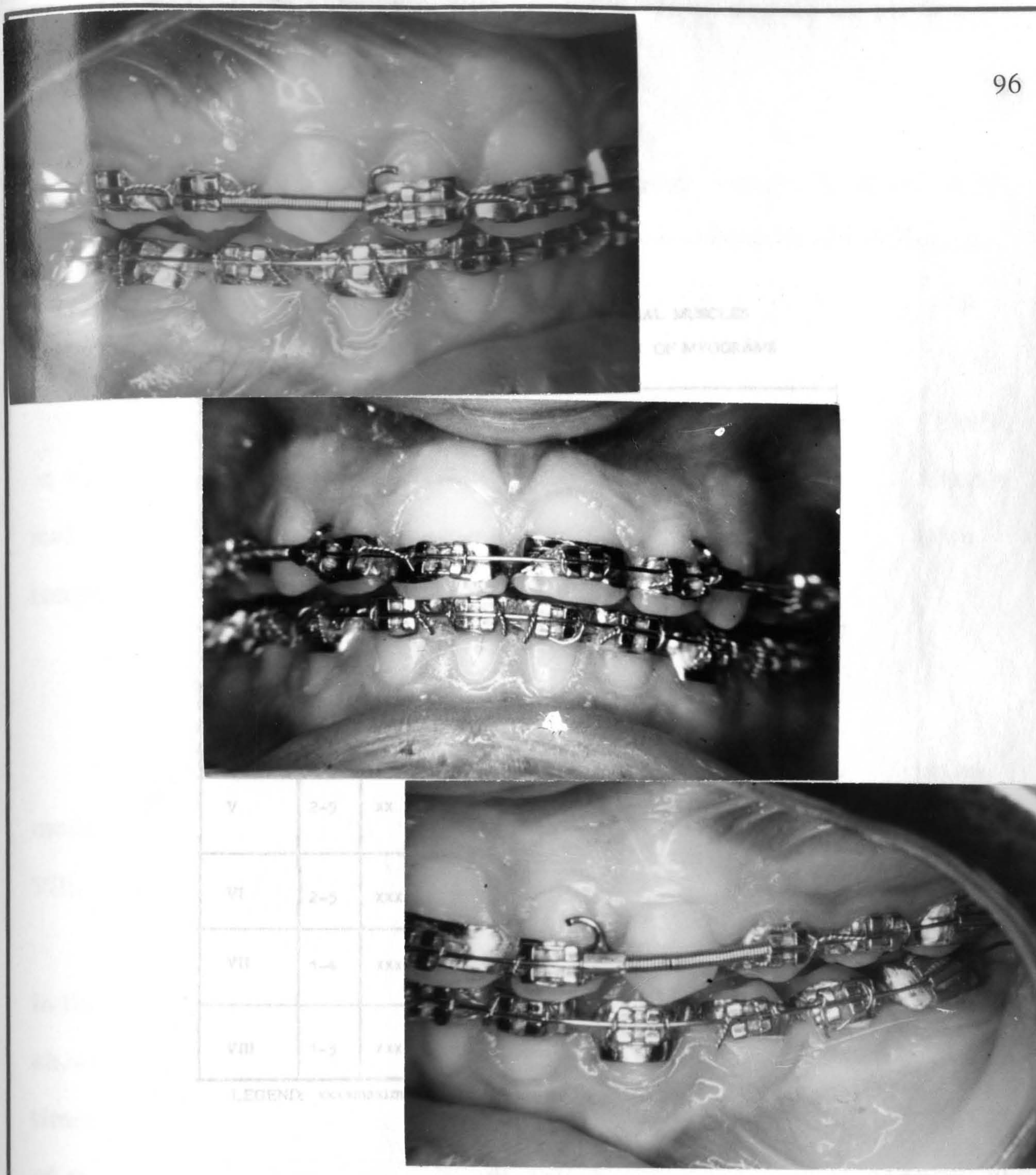


FIGURE 35

INTRAORAL PHOTOGRAPHS OF SUBJECT #6

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART I COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 6 K. M.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	3-6	XX	XX	XXX	LEFT MASS.	XX	XX	XXX
II	2-5	XX	XX	XXX	LEFT MASS.	XX	XX	XXX
III	3-5	XX	XX	XXX	LEFT MASS.	XX	XX	XXX
IV	2-6	XXX	XXX	XXX	LEFT MASS.	XX	XXX	XX
V	2-5	XX	XX	XXX	LEFT MASS.	XX	XX	X-XX
VI	2-5	XXX	XX	XXX	LEFT MASS.	XX	XX	XX
VII	1-4	XXX	XX	XX	POST. TEMP. LEFT MASS.	XX	XX	XX
VIII	1-3	XXX	XX	X	LT. POST. TEMP.	XX	XX	0

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 36

DURATION was moderate in all experiments except Experiment IV.

NODING was maximum from the first experiment through Experiment VI, after which it decreased to moderate in Experiment VII, and then to minimum in Experiment VIII.

SUSTAINED LOW AMPLITUDE occurred in the left masseter only in Experiments I through VI; in Experiment VII in the posterior temporals and the left masseter; and in Experiment VIII only in the left posterior temporal.

RATE OF ONSET was moderate during all the experiments.

RATE OF ENDING was moderate during all the experiments.

INTERIM ACTIVITY was maximum in the first three experiments, moderate in the next four experiments, and disappeared in Experiment VIII.

INITIATION OF CHEWING ACTIVITY (Figure 37) showed a decrease in the number of times the masseter initiated the chewing cycle and showed an increase followed by a decrease to zero in the number of times the temporal initiated the chewing activity. Synchronous initiation of the chewing activity shows a general slight increase from Experiments I to VIII.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 6. K. M.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	8	2	3	0	0	0	1	4
Masseter and middle temporal first	0	1	1	1	0	0	0	0
Masseter and posterior temporal first	0	0	2	0	0	0	0	0
Middle and posterior temporal first	1	7	3	5	2	8	2	0
Middle temporal first	0	0	1	0	1	0	0	2
Posterior temporal first	0	1	0	4	0	0	0	0
All together (Synchrony)	3	1	2	2	9	4	9	6
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 37

SUMMARY:

There was a decrease in the number of times the masseter initiated the chewing cycle and a slight increase in the number of times a synchronous initiation occurred. As treatment progressed, there was a decrease in the amount of inhibition (decrease in the number of bursts); an increase in amplitude; and a very marked decrease in the interim activity.

Subject #7 (J.N.)

Male

Age, fifteen years

Angle Classification of Malocclusion, Class II, Division 1 (Figure 38)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 39): consolidation of mandibular anterior teeth. The appliance consisted of a mandibular contraction loop archwire and a consolidation arch in the maxilla. There were no elastics used in this stage.

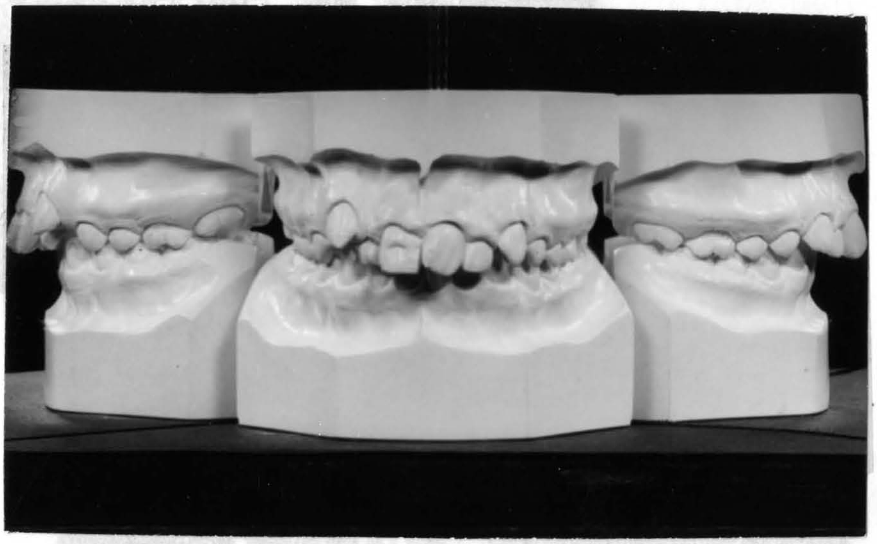
Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 40):

BURSTS were within the same range for the first four experiments; but beginning with Experiment V, there was a continous decrease in the number of bursts through Experiment VIII.

AMPLITUDE was maximum except for Experiments IV, V, and VI, where it was moderate.

DURATION was moderate except for Experiments II and IV.

NODING was moderate in the first experiment, increased to



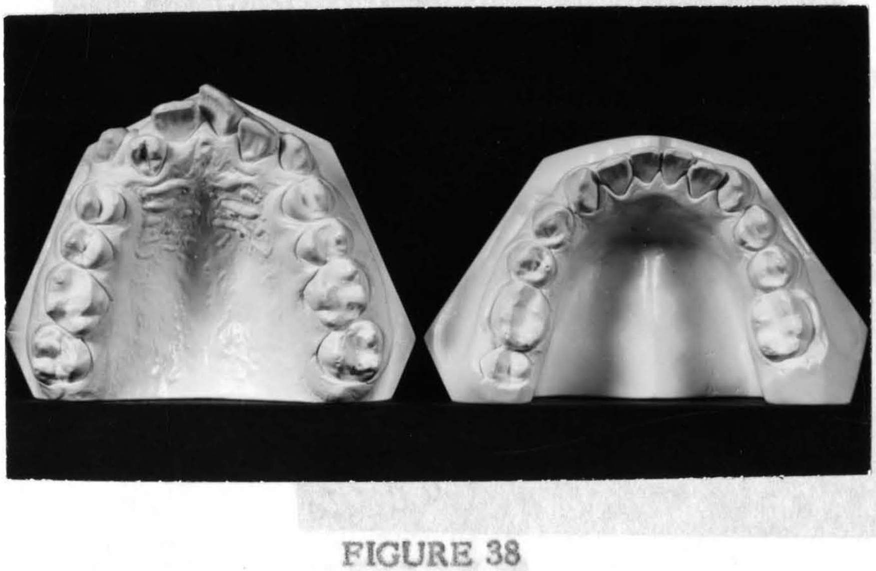


FIGURE 38

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #7

BEFORE ORTHODONTIC TREATMENT

FIGURE 39

INTRAORAL PHOTOGRAPHS OF SUBJECT #7

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 7 J. N.								
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	6-8	XXX	XX	XX	RIGHT MASS.	XX	XXX	XX
II	6-8	XXX	XXX	XXX	O	XX	XX	XX
III	6-8	XXX	XX	XX	RIGHT MASS.	XX	XX	X
IV	6-8	XX	XXX	XX	X- RIGHT MASS.	XX	XX	XXX POST. TEMP.
V	2-5	XX	XX	XX	O	XX	XX	XX- MASS. & PT. TEMP.
VI	3-5	XX	XX	XX	X	XX	XX	XX- POST. TEMP.
VII	1-4	XX-XXX	XX	XX	X	XX	XX	X
VIII	1-3	XXX	XX	X	O	X	XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 40

maximum in the second, and returned to moderate in the third experiment where it remained until Experiment VIII. In Experiment VIII it decreased to minimum.

SUSTAINED LOW AMPLITUDE occurred in the right masseter in Experiments I, III, and IV. In Experiment VIII it disappeared.

RATE OF ONSET was moderate in all experiments except in Experiment VIII where it was minimum.

RATE OF ENDING was maximum in the first experiment and moderate in the succeeding experiments.

INTERIM ACTIVITY was moderate in the first two experiments; decreased in Experiment III to minimum; was maximum in the posterior temporal in Experiment IV; was moderate in the masseter and posterior temporal in Experiments V and VI; and decreased to minimum in Experiments VII and VIII.

INITIATION OF THE CHEWING ACTIVITY (Figure 41) showed a change in the division of labor between the muscles during the eight experiments; but the muscles still initiated the chewing cycle about the same number of times in Experiment VIII as they did in Experiment I.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 7 J. N.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	3	7	5	4	4	1	1	4
Masseter and middle temporal first	2	2	0	0	1	0	0	0
Masseter and posterior temporal first	0	0	0	1	0	0	2	0
Middle and posterior temporal first	0	0	1	0	0	1	0	1
Middle temporal first	0	0	0	0	0	0	0	0
Posterior temporal first	0	0	0	5	0	1	0	0
All together (Synchrony)	7	3	6	2	7	9	9	7
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 41

SUMMARY

As treatment progressed, there was a very sharp decrease in the amount of inhibition (decrease in the number of bursts), a disappearance of sustained low amplitude, a slight decrease in the interim activity, and in Experiment VIII a return to a similar initiation of chewing activity as occurred in Experiment I.

Subject #8 (L.P.)

Female

Age, fourteen years

Angle Classification of Malocclusion, Class II, Division 1 (Figure 42)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 43): the active appliance had been removed and the patient was now using a rubber finishing appliance for functional retention of the teeth.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 44):

BURSTS decreased as treatment progressed.

AMPLITUDE was maximum in the first experiment and continued to remain at that level. In Experiment VIII it ranged from minimum to maximum.

DURATION varied from minimum in Experiments I to maximum in Experiment IV. In Experiments V and VI there is a slight decrease which levels off at moderate in Experiments VII and VIII.

NODING was maximum in Experiment I and this tended to remain

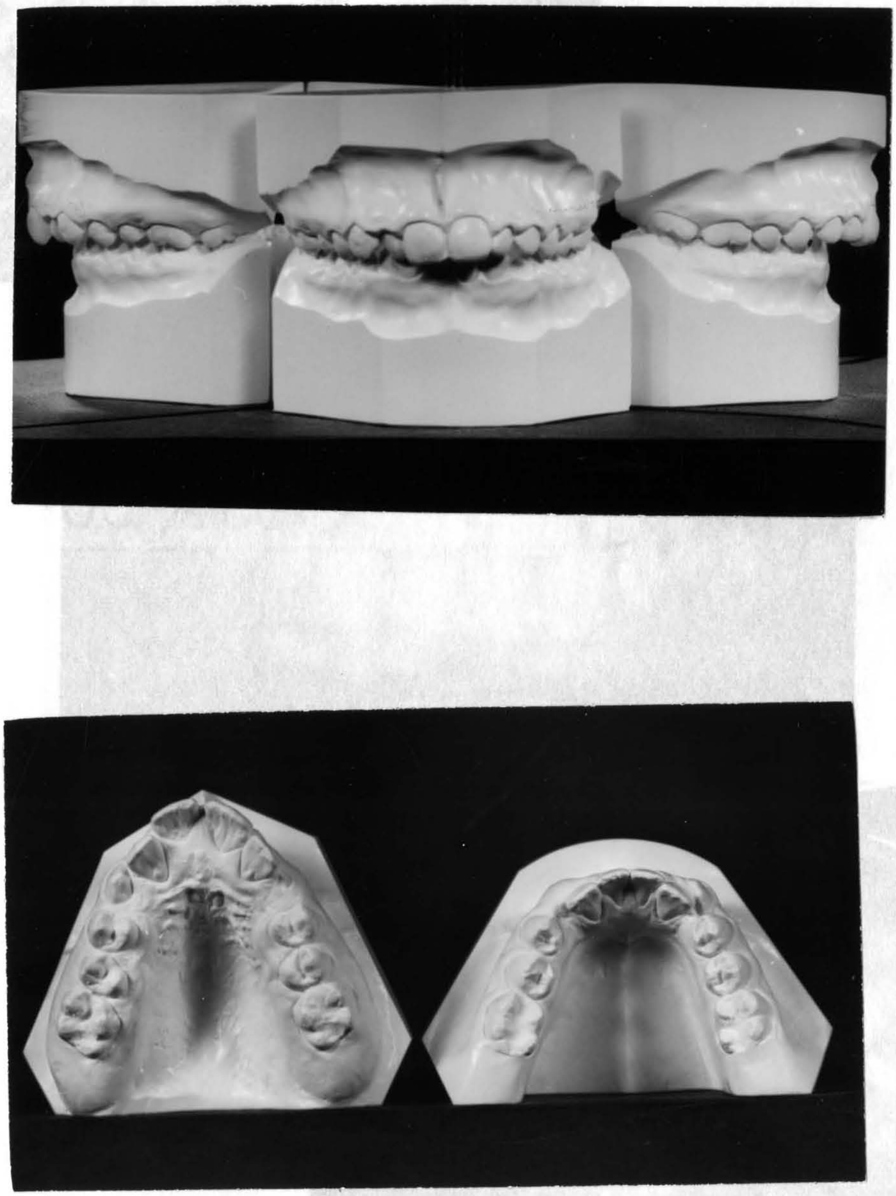


FIGURE 42

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #8

BEFORE ORTHODONTIC TREATMENT

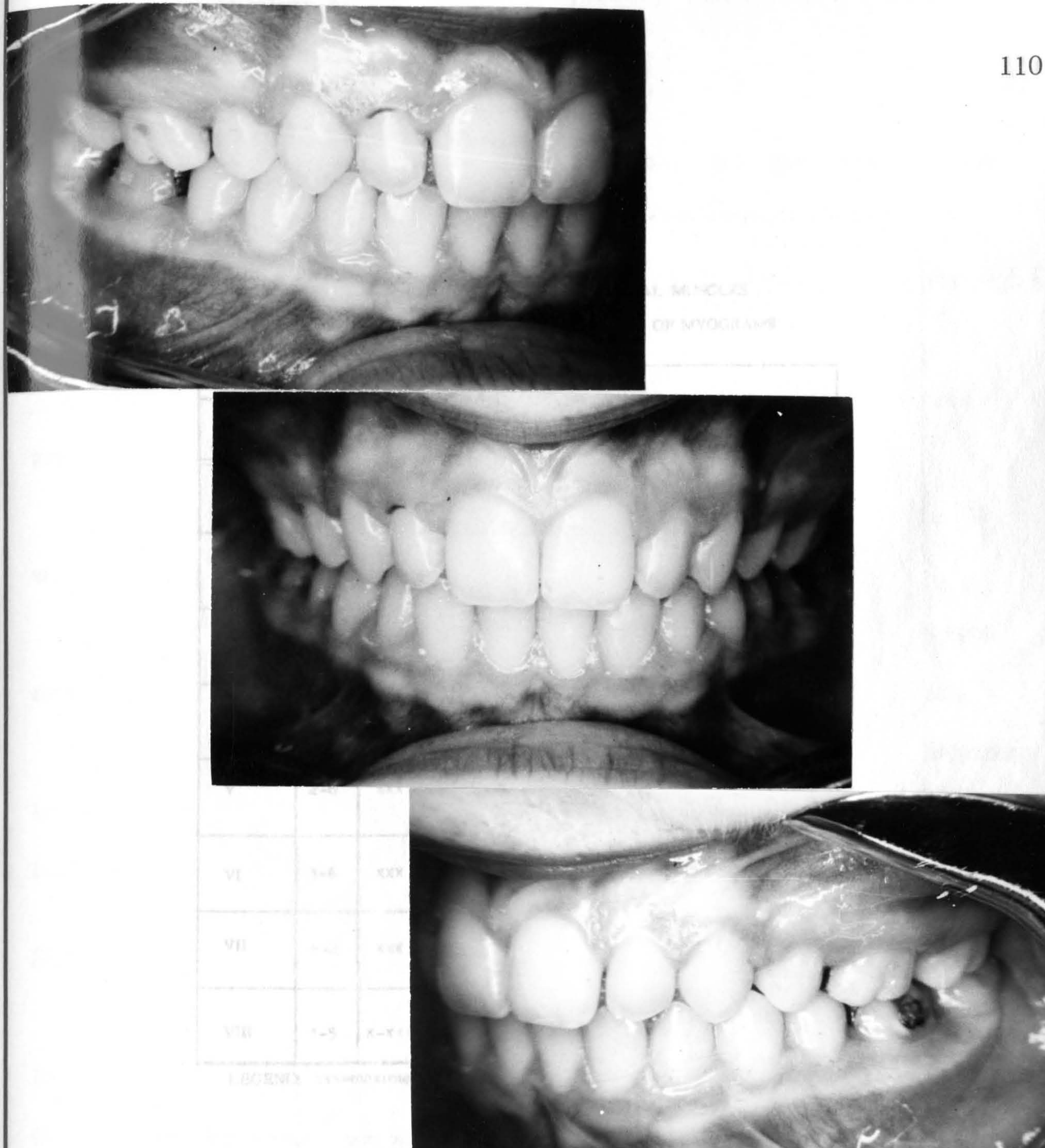


FIGURE 43

INTRAORAL PHOTOGRAPHS OF SUBJECT #8

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 8 L. P.								
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-6	XXX	X	XXX	X- MID. TEMP.	XX	XX	XXX
II	2-5	XX	XX	XX	MASS. & MIDDLE TEMP. X	XX	XX	XX
III	2-6	XXX	X	XXX	X- MASS.	XX	XX	XXX
IV	2-6	XX	XXX	XXX	X- ALL MUSCLES	X	X	XXX
V	2-6	XXX	XX-XXX	XXX	X- MASS.	XX	XX	XX
VI	3-6	XXX	XX-XXX	XXX	X- MASS.	XX	XX	XXX
VII	1-8	XXX	XX	XX	XX- ALL MUSCLES	XX	XX	XX-XXX
VIII	1-5	X-XXX	XX	X-XX	X- ALL MUSCLES	X-XX	XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 44

until Experiment VII where it became moderate. In Experiment VII there was a further decrease varying between minimum and moderate.

SUSTAINED LOW AMPLITUDE was minimum in all muscles throughout the whole of the study.

RATE OF ONSET was moderate in all the experiments except IV and VIII where there was a slight decrease.

RATE OF ENDING was moderate in all experiments except in IV where it was minimum.

INTERIM ACTIVITY was maximum to moderate in the first seven experiments. In Experiment VIII this activity decreases to minimum.

INITIATION OF CHEWING ACTIVITY (Figure 45) showed a decrease in the initiation of the chewing cycle by the masseter and very definite increase in the synchronous initiation of chewing activity by all muscles.

SUMMARY:

As treatment progressed, there was a decrease in the amount of inhibition (decrease in the number of bursts), and a marked decrease in the interim activity. The sustained low amplitude was not eliminated. There was a decrease in the number of times the masseter initiated the chewing activity and a decrease in the number of times that synchronous

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 8. L. P

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	6	5	5	5	3	5	5	0
Masseter and middle temporal first	0	0	0	1	0	0	1	0
Masseter and posterior temporal first	0	0	1	1	0	0	0	0
Middle and posterior temporal first	2	4	3	1	3	0	1	0
Middle temporal first	0	0	0	0	1	0	2	0
Posterior temporal first	0	0	0	1	0	0	1	1
All together (Synchrony)	4	3	3	3	5	7	2	11
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 45

initiation occurred.

Subject #9 (C.R.)

Female

Age, thirteen years

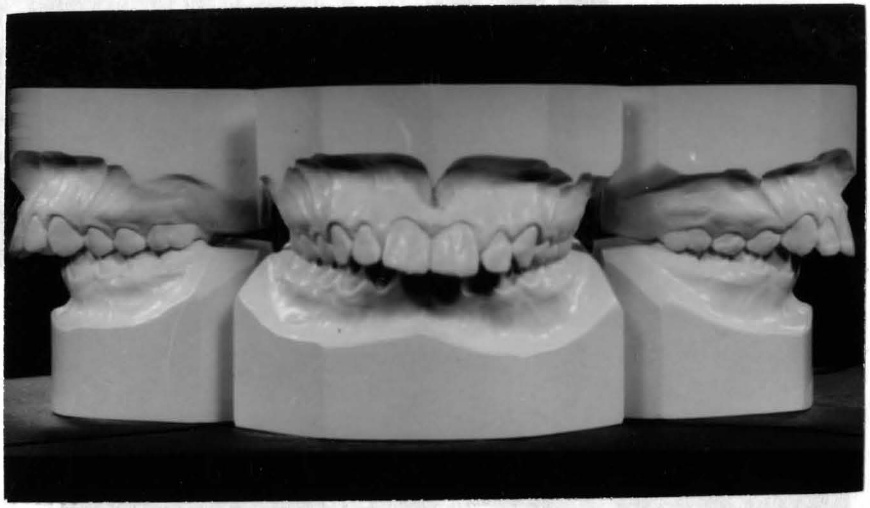
Angle Classification of Malocclusion, Class II, Division 1 (Figure 46)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 47): consolidation of the spaces between the anterior teeth in the maxillary arch and consolidation of the space between the canines and the bicuspids in the mandibular arch. The appliance consisted of a consolidation archwire in the maxilla and a contraction loop archwire in the mandible. Class II heavy quarter-inch elastics and high-pull headgear were used.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 48):

BURSTS remained high from Experiment I through IV, and decreased steadily from then on through Experiment VIII.

AMPLITUDE was minimum to moderate in the first two experiments, increased in Experiments III and IV, decreased in V and VI, increased in VII and then decreased again in VIII.



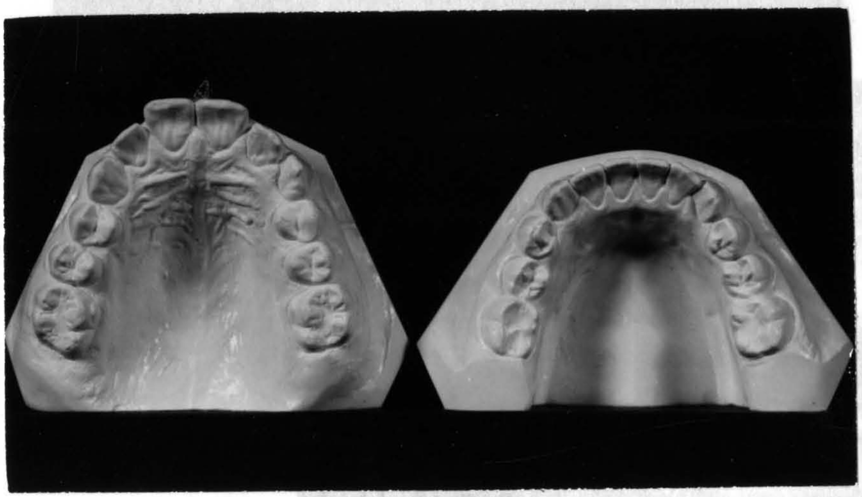


FIGURE 46

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #9

BEFORE ORTHODONTIC TREATMENT

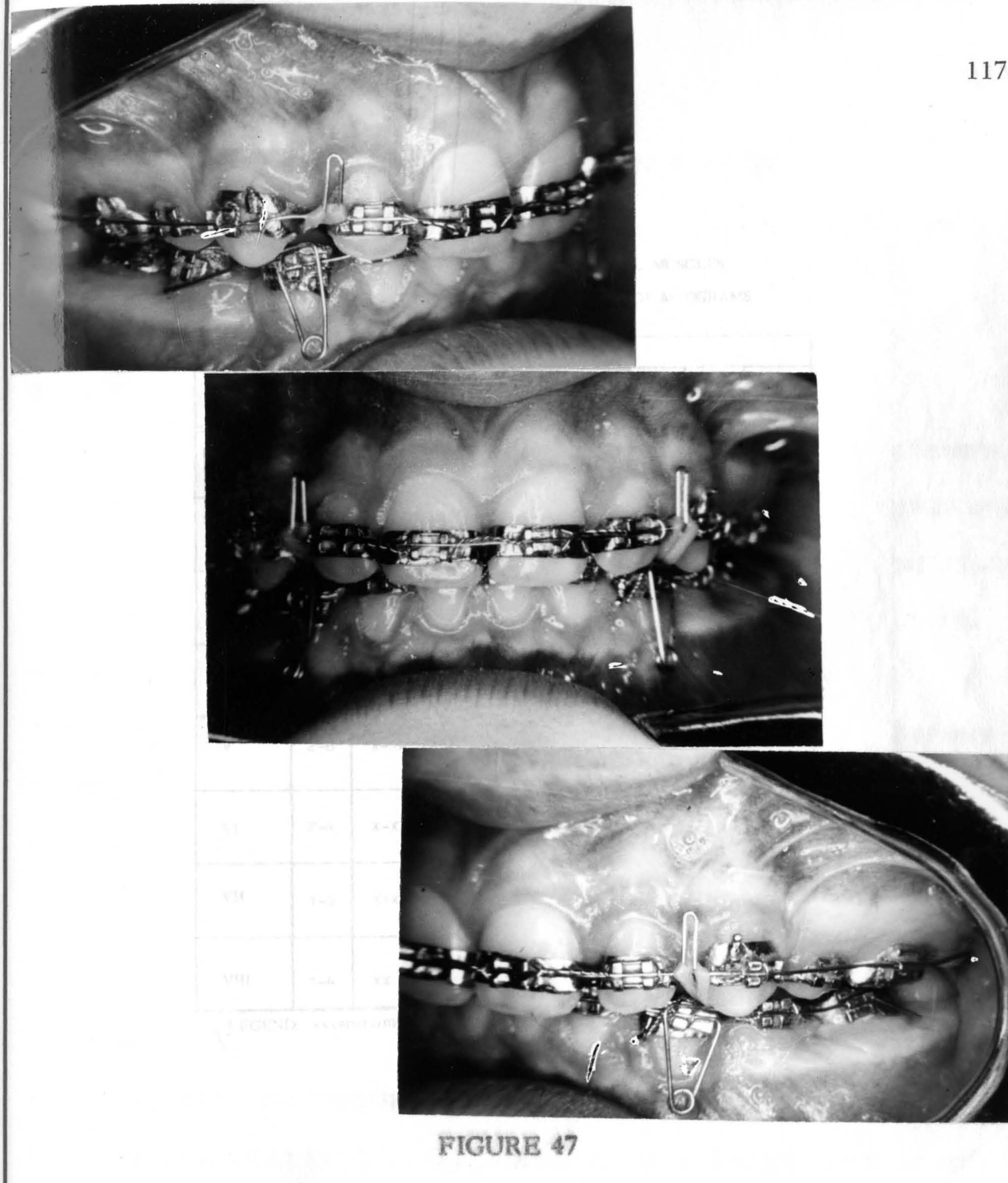


FIGURE 47

INTRAORAL PHOTOGRAPHS OF SUBJECT #9

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 9 C. R.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	6-8	X-XX	XX	XXX	X-MASS.	XX	XX	X
II	6-8	X-XX	XX	XX	X-MASS.	XX	XX	X
III	6-8	XX-XXX	XX	XXX	0	XX	XX	X
IV	6-8	X-XXX	XXX	XXX	X-MASS.	X	XX	X
V	2-6	X-XX	XX-XXX	XXX	X-MASS.	XX	X-XX	X
VI	2-4	X-XX	XX	XX	X-MASS.	XX	X	X
VII	1-5	XXX	XX	X-XX	0	X-XXX	X-XX	X-XX
VIII	1-4	XX	XX	XX	0	X-XX	X-XX	0

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 48

DURATION was moderate in all experiments except in V.

NODING was maximum in Experiments I, III, IV, and V, and was moderate in the remaining experiments.

SUSTAINED LOW AMPLITUDE occurred in the masseter in all epxeriments except in III, VII, and VIII where it disappeared.

RATE OF ONSET remained moderate throughout all the experiments.

RATE OF ENDING was moderate for the first four experiments, and then varied between minimum and moderate for the remaining experiments.

INTERIM ACTIVITY was minimum in all experiments except in VIII where it disappeared.

INITIATION OF CHEWING ACTIVITY (Figure 49) showed a decrease in the activity of the masseter and a steady increase in the synchronous initiation of the chewing stroke.

SUMMARY:

As treatment progressed, there was a marked decrease in inhibition (as shown by the decrease in the number of bursts), a decrease in the number of times the masseter initiated the chewing activity, an increase in synchronous initiation of chewing activity, and a disappearance of both sustained low amplitude and interim activity.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 9. C. R.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	3	4	3	0	0	1	1	0
Masseter and middle temporal first	0	0	0	0	0	0	0	0
Masseter and posterior temporal first	0	0	1	0	0	0	1	0
Middle and posterior temporal first	2	2	1	6	3	3	0	2
Middle temporal first	0	0	0	1	0	0	0	0
Posterior temporal first	2	2	1	1	0	0	0	1
All together (Synchrony)	5	4	6	4	9	8	10	9
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 49

Subject #10 (H. S.)

Male

Age, sixteen years

Angle Classification of Malocclusion, Class 1 (Figure 50)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 51): the active appliance had been removed and the patient was now using a rubber finishing appliance for functional retention of the teeth.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 52):

BURSTS showed a gradual increase in number from Experiment I through Experiment VI. Experiment VII showed a marked decrease which continued through Experiment VIII.

AMPLITUDE was maximum in all experiments except in Experiments IV and V where it was moderate.

DURATION was minimum in the first three experiments, and then increased gradually to maximum in Experiment VII; in Experiment VIII it decreased to moderate.

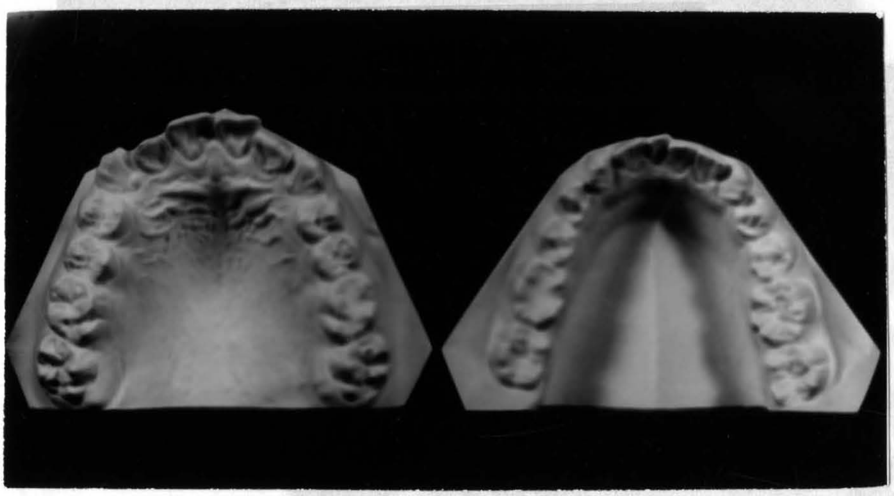


FIGURE 50

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #10

BEFORE ORTHODONTIC TREATMENT

FIGURE 51

INTRAORAL PHOTOGRAPHS OF SUBJECT #10

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART I COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 10 H. S.								
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-3	XXX	X	X	X-MASS.	XX	XXX	X
II	2-3	XXX	X	X	X	XX	XXX	X
III	2-4	XXX	X	XX	X-MASS.	XX	XXX	X
IV	2-6	XX	XX	XX	0	XX	XXX	XX
V	3-6	XX-XXX	XXX	XXX	XX-XXX MASS.	XX	XXX	X
VI	4-7	XXX	XX-XXX	XXX	XX-MASS.	XX	XXX	XX
VII	1-4	XXX	XXX	X-XXX	X-POST. TEMP. & MASS.	X-XXX	X-XXX	X-XX
VIII	1-3	XXX	XX	X	0	XX	XX	0

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 52

NODING increased from minimum in Experiment I to maximum in Experiment VII. Experiment VIII showed a sharp decrease to minimum.

SUSTAINED LOW AMPLITUDE occurred in the masseter and posterior temporals except in Experiments IV and VIII.

RATE OF ONSET was moderate throughout the experiments.

RATE OF ENDING was maximum in all experiments except in Experiment VIII where it was moderate.

INTERIM ACTIVITY was minimum in Experiments I, II, III, and V. In Experiment IV, VI, and VII it was moderate, and then decreased to minimum in Experiment VIII.

INITIATION OF CHEWING ACTIVITY (Figure 53) showed a decrease in the initiation of the chewing cycle by the masseter and a steady increase in the synchronous initiation of the chewing activity. The middle and posterior temporals were eliminated in the initiation of the chewing cycle.

SUMMARY:

As treatment progressed, there was a decrease in inhibition, a disappearance of both sustained low amplitude and interim activity, and an increase in the synchronous initiation of the chewing stroke by all muscles.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 10. H. S.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	2	3	0	0	3	2	3	0
Masseter and middle temporal first	1	1	2	1	0	0	1	0
Masseter and posterior temporal first	0	0	1	0	0	0	0	1
Middle and posterior temporal first	3	1	5	3	3	5	0	0
Middle temporal first	1	1	0	0	0	0	0	0
Posterior temporal first	0	0	0	2	0	2	0	0
All together (Synchrony)	5	6	4	6	6	3	8	11
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 53

Subject #11 (E.S.)

Female

Age, fourteen years

Angle Classification of Malocclusion, Class II, Division 1 (Figure 54)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 55): the active appliance had been removed and the patient was using a rubber finishing appliance for functional retention of the teeth.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 56):

BURSTS remained similar for the first seven experiments and decreased in Experiment VIII.

AMPLITUDE was moderate in Experiments I and II, minimum in Experiment III, and moderate in Experiment IV. The remaining four experiments showed a varying range from minimum to maximum, with minimum amplitude in the masseters, and maximum in the posterior temporals.

DURATION was maximum on the left side throughout the whole study

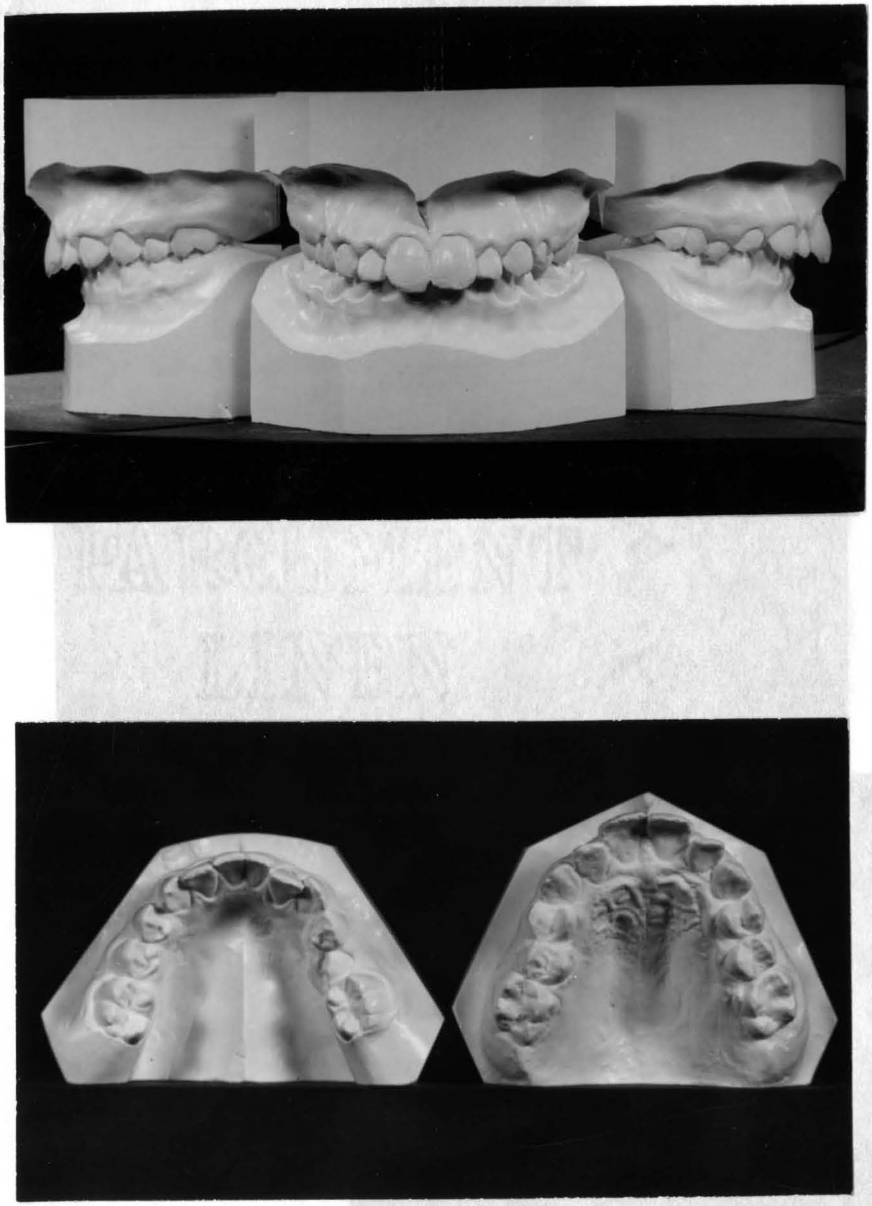


FIGURE 54

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #11

BEFORE ORTHODONTIC TREATMENT

FIGURE 55

INTRAORAL PHOTOGRAPHS OF SUBJECT #11

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT	NUMBER: 11 E. S.							
Exp. No.	**Bursts**	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-7	XX	XX-XXX	XX	X-MASS.	XX	XX	XX-XXX
II	2-7	XX	XXX	XX	X-MASS.	XX	XX	XX-XXX
III	2-7	X	XX-XXX	XXX	X-MASS.	XX	XX	XX
IV	2-7	XX	XX-XXX	XX	0	XX	XX	X-XXX
V	2-6	X-XXX	XX-XXX	XX	X-MASS.	XX	X-XX	X
VI	2-7	X-XXX	XXX	XXX	X-MASS.	XX	X-XX	X
VII	2-6	X-XXX	XX	XX	X-MASS.	XX	X-XX	XX
VIII	1-5	XX-XXX	XX-XXX	XX	0	XX	XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 56

except in Experiment VII. The right side was moderate in amplitude except in Experiment II and VI.

NODING was moderate throughout the experiments except for Experiments III and VI.

SUSTAINED LOW AMPLITUDE was evident in the masseter except in Experiments IV and VIII.

RATE OF ONSET was moderate for all experiments.

RATE OF ENDING was moderate for all experiments, but decreased somewhat during Experiments V, VI, and VII.

INTERIM ACTIVITY was moderate to maximum for the first four experiments, and then decreased to minimum for the remaining experiments except in VII when it was moderate.

INITIATION OF CHEWING ACTIVITY (Figure 57) showed a decrease in the initiation of the chewing cycle by the masseter, an increase and then decrease by the middle and posterior temporals, and an increase in the synchronous initiation by all muscles.

SUMMARY:

As treatment progressed, there was a decrease in the amount of

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 11. E. S.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	3	5	4	2	1	0	1	0
Masseter and middle temporal first	1	1	1	0	0	0	0	0
Masseter and posterior temporal first	0	1	2	0	0	0	0	0
Middle and posterior temporal first	1	2	2	2	1	7	5	0
Middle temporal first	0	0	1	0	0	0	0	0
Posterior temporal first	0	1	0	3	1	0	0	0
All together (Synchrony)	7	2	2	5	9	5	6	12
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 57

inhibition, a disappearance of sustained low amplitude, and a decrease in the interim activity.

Subject #12 (J.S.)

Female

Age, sixteen years

Angle Classification of Malocclusion, Class II, Division 1 (Figure 58)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 59): the active appliance had been removed and the patient was using a rubber finishing appliance for functional retention of the teeth.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 60):

BURSTS were the same for the first four experiments. In Experiments V and VI there was an increase in the number of bursts; and, beginning with Experiment VII and continuing through Experiment VIII, there was a decrease in the number of bursts.

AMPLITUDE remained the same throughout the eight experiments.

DURATION varied between minimum and maximum for the first four experiments. In Experiments V, VI, and VII it remained maximum and decreased in Experiment VIII to moderate.

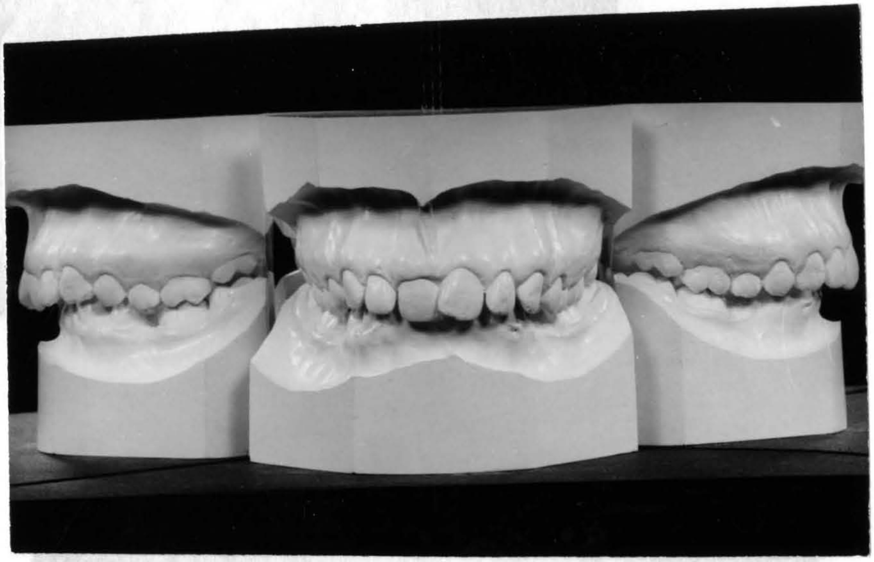


FIGURE 58

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #12

BEFORE ORTHODONTIC TREATMENT

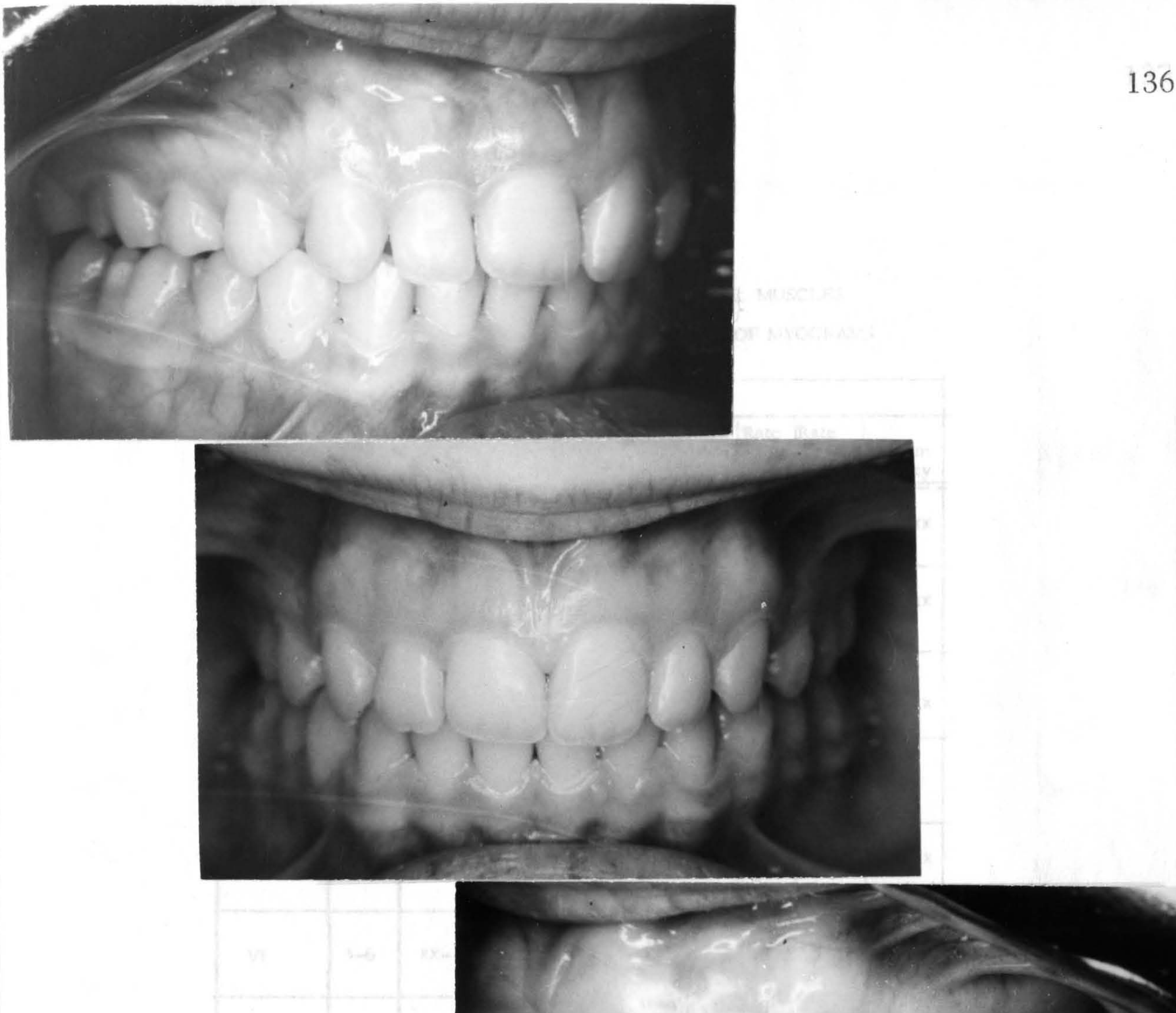


FIGURE 59

INTRAORAL PHOTOGRAPHS OF SUBJECT #12

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT	NUMBER: 12 J. S.							
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-8	XX-XXX	X-XXX	X-XXX	0	XX	XX	X-XXX
II	2-8	XX-XXX	XX-XXX	XXX	0	XX	XX	XX-XXX
III	2-8	XX-XXX	X-XXX	XXX	0	XX	XX	X-XXX
IV	2-8	XX-XXX	XX-XXX	XXX	0	XX	XX	X
V	3-5	XX-XXX	XXX	XXX	0	XX	XX	X-XXX
VI	3-6	XX-XXX	XXX	XXX	X-MASS.	XX	XXX	X-XX
VII	2-8	XX-XXX	XXX	XXX	X-POST. TEMP.	XX-XXX	XX-XXX	X
VIII	1-5	XX-XXX	XX	X-XX	0	X-XX	XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 60

NODING was maximum in all experiments except in Experiment VIII where it was moderate to minimum.

SUSTAINED LOW AMPLITUDE occurred only in Experiments VI (in the masseter) and VII (in the posterior temporal).

RATE OF ONSET remained about the same throughout the experiments.

RATE OF ENDING was moderate in all experiments except Experiments VI and VII.

INTERIM ACTIVITY was minimum to maximum in the first three experiments; minimum in IV; increased in V and VI; and then decreased to minimum in VII and VIII.

INITIATION OF CHEWING ACTIVITY (Figure 61) showed a decrease in the initiation of chewing activity by the masseter and an irregular variation in the synchronous initiation of chewing.

SUMMARY:

As treatment progressed, there was a decrease in the amount of inhibition; a decrease in the interim activity; and a decrease in the number of times the masseter initiated the chewing cycle. The direction of the trend of synchronous action of the muscles was not obvious.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 12. J. S.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	5	7	4	2	0	0	0	2
Masseter and middle temporal first	1	1	0	0	1	0	0	1
Masseter and posterior temporal first	1	1	0	1	0	0	0	1
Middle and posterior temporal first	2	0	1	3	1	7	1	0
Middle temporal first	0	0	1	1	0	0	0	0
Posterior temporal first	0	0	2	1	0	3	2	3
All together (Synchrony)	3	3	4	4	10	2	9	5
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 61

Subject #13 (A.G.)

Female

Age, thirteen years

Angle Classification of Malocclusion, Class II, Division 1 (Figure 62)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 63): leveling of the occlusal plane in the maxilla, correcting the cross bite of the left mandibular buccal segment. The appliance consisted of a leveling archwire in the maxilla and an ideal rectangular archwire in the mandible. The elastics were: 1) heavy quarter-inch triangular elastics on right side only; 2) heavy quarter-inch elastic to correct cross bite in buccal segment; and 3) class II heavy elastics.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 64):

BURSTS increased in number in Experiment III over Experiments I and II. This increased number of bursts remained until Experiment VII when it decreased. Experiment VIII remained the same as VII which was less in number than the original records.

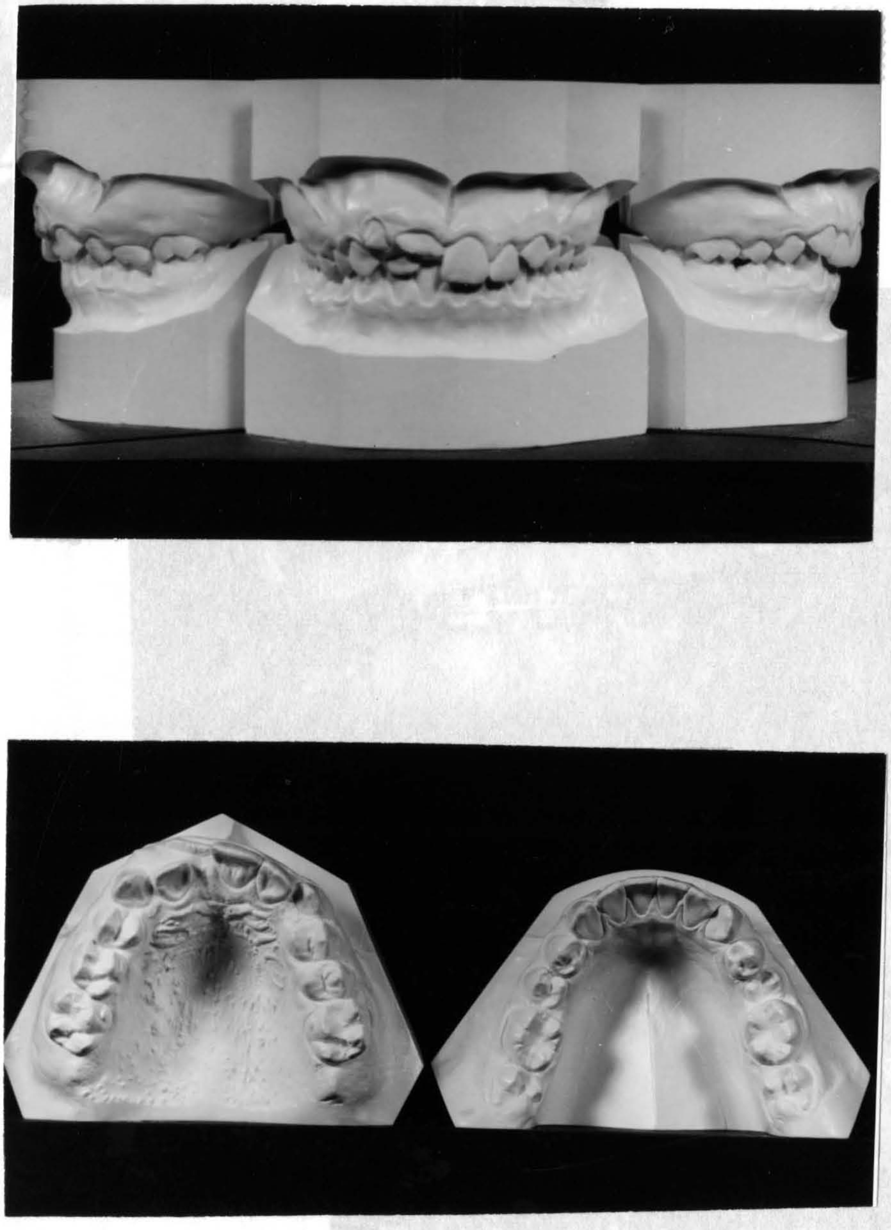


FIGURE 62

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #13

BEFORE ORTHODONTIC TREATMENT

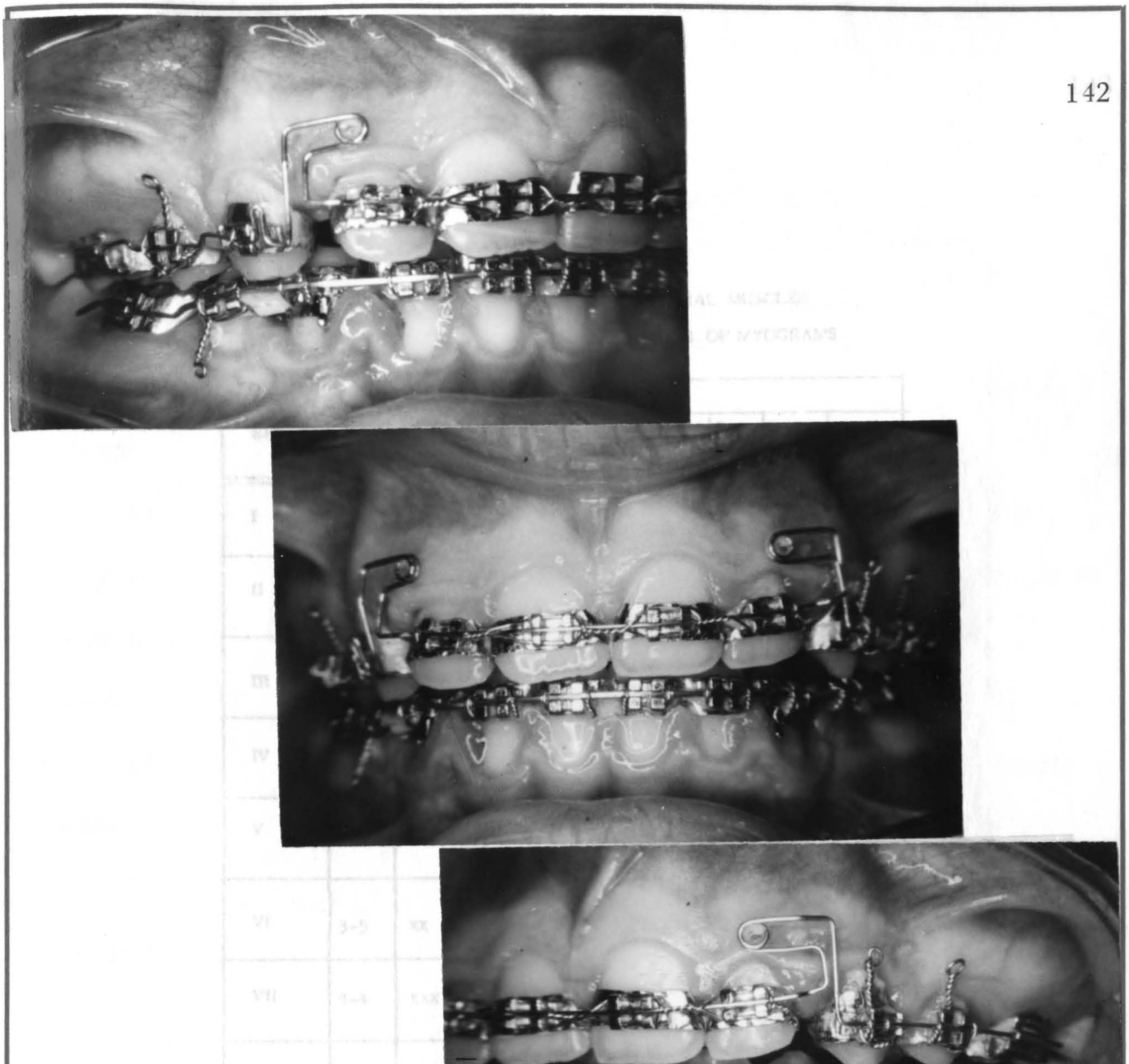


FIGURE 63

INTRAORAL PHOTOGRAPHS OF SUBJECT #13

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 13 A. S.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-3	XXX	XX	XX	0	XX	XX	XXX
II	3	XX	X	XXX	XX	XX	XX	XX
III	2-5	XXX	X	XXX	0	XX	XX	XX
IV	2-5	XXX	XX	XXX	0	XX	XX	X
V	2-5	XX	XX	XX	XX-MASS.	XX	XX	X
VI	3-5	XX	XX	XXX	XX-MASS.	XX	XXX	X
VII	1-4	XXX	XX	X-XX	X-ALL MUSCLES	XX	X-XX	XXX
VIII	1-4	XX-XXX	XX	XX	X-ALL MUSCLES	X-XX	X-XX	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 64

AMPLITUDE was maximum in Experiments I, III, IV, VII, and VIII. It was moderate in the other experiments.

DURATION was moderate in all experiments except II and III.

NODING increased from moderate in Experiment I to maximum in Experiment II where it remained through Experiment VIII.

SUSTAINED LOW AMPLITUDE occurred in Experiments II, V, VI, VII, and VIII. In Experiments VII and VIII there was a minimum amount in all muscles whereas in V and VI there was moderate sustained low amplitude in only the masseters.

RATE OF ONSET was moderate throughout the first seven experiments and then decreased in the eighth experiment.

RATE OF ENDING was moderate in the first five experiments, maximum in the sixth, and minimum to moderate in the seventh and eighth experiments.

INTERIM ACTIVITY was maximum in Experiments I and VII, moderate in Experiments II and III, and minimum in the remaining experiments.

INITIATION OF CHEWING ACTIVITY (Figure 65) showed a decrease in the initiation of chewing activity by the masseter and an increase in the synchronous initiation of chewing by all muscles.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 13. A.S.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	6	3	2	3	1	3	3	2
Masseter and middle temporal first	1	3	1	1	0	0	0	0
Masseter and posterior temporal first	1	0	1	0	0	0	0	1
Middle and posterior temporal first	1	1	1	2	3	4	1	0
Middle temporal first	0	0	1	0	0	1	0	0
Posterior temporal first	0	0	0	0	0	0	0	0
All together (Synchrony)	3	5	6	6	8	4	8	9
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 65

SUMMARY:

As treatment progressed, there was a decrease in the amount of inhibition, a decrease in interim activity; a decrease in the number of times the masseter initiated the chewing activity; and an increase in the number of times there was a synchronous initiation.

Subject #14 (D.T.)

Male

Age, fifteen years

Angle Classification of Malocclusion, Class I, Pseudo Class III (Figure 66)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 67): the active appliance had been removed and the patient was using a rubber finishing appliance for functional retention of the teeth.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 68):

BURSTS remained about the same for the first six experiments, but decreased in number in Experiments VII and VIII.

AMPLITUDE was moderate in Experiments I, III, IV; was minimum in Experiments II, V, and VI; and was maximum in Experiments VII and VIII.

DURATION tended to be moderate throughout all the experiments.

NODING was maximum in all but three experiments. It was moderate in Experiment II, moderate to minimum in Experiment VII, and decreased

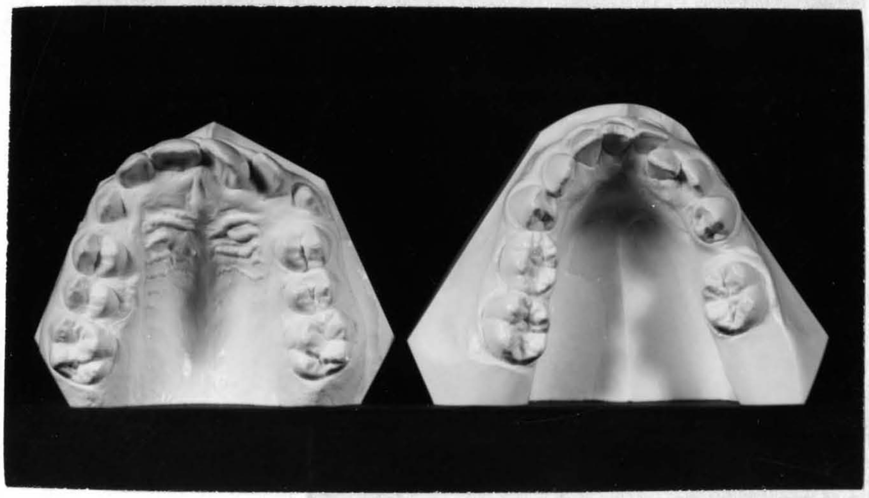


FIGURE 66

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #14

BEFORE ORTHODONTIC TREATMENT

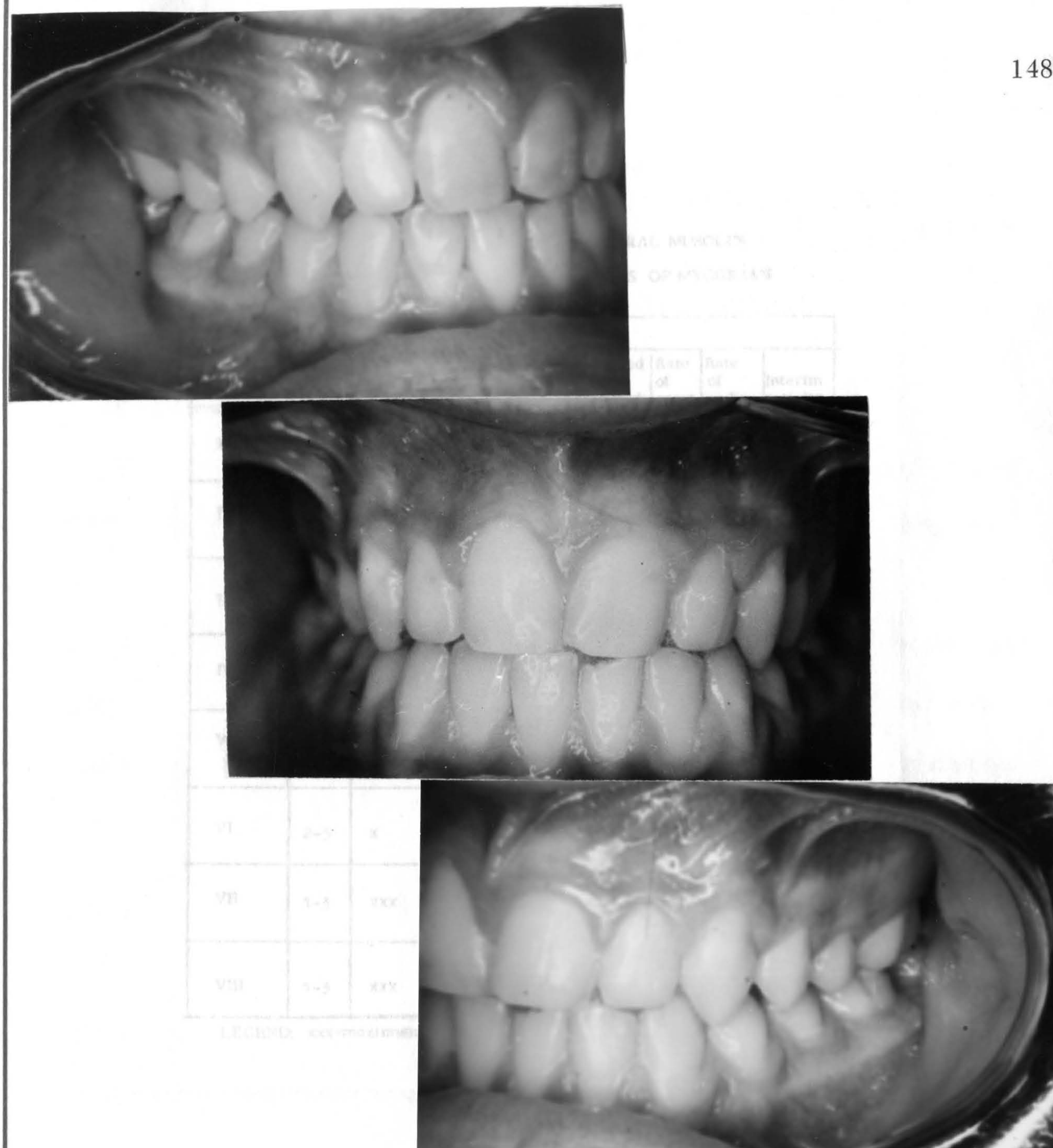


FIGURE 67

INTRAORAL PHOTOGRAPHS OF SUBJECT #14

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 14 D. T.								
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	2-6	XX	XX	XXX	X	XX	XX	X
II	2-4	X	XX	XX	X	XX	XX	X
III	3-5	XX	XX	XXX	X	XX	XX	X
IV	3-6	XX	XX-XXX	XXX	0	XX	XX	XX
V	2-6	X	XX	XXX	X	XX	XX	X
VI	2-5	X	XX	XXX	X-MASS.	XX	XX	X
VII	1-3	XXX	XX-XXX	X-XX	0	X-XX	X-XX	X-XX
VIII	1-3	XXX	XX	X	0	XX	XX	0

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change.

FIGURE 68

to minimum in Experiment VIII.

SUSTAINED LOW AMPLITUDE occurred in all but Experiments IV, VII, and VIII.

RATE OF ONSET was moderate throughout the study.

RATE OF ENDING was moderate throughout the study.

INTERIM ACTIVITY was minimum in all experiments except III, IV, and VIII. It was moderate in III and IV, and disappeared in Experiment VIII.

INITIATION OF CHEWING ACTIVITY (Figure 69) showed a decrease in the number of times the masseter initiated the chewing cycle, and an increase in the number of times there was a synchronous initiation by all muscles.

SUMMARY:

As treatment progressed, there was a decrease in the amount of inhibition; an increase in the amplitude; and a disappearance of both sustained low amplitude and interim activity.

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 14. D. T.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	6	3	3	0	3	1	0	0
Masseter and middle temporal first	0	1	0	0	0	0	0	0
Masseter and posterior temporal first	1	0	1	0	0	0	0	0
Middle and posterior temporal first	2	2	3	2	6	4	6	1
Middle temporal first	1	0	0	0	0	0	0	0
Posterior temporal first	0	1	1	5	0	1	0	0
All together (Synchrony)	2	5	4	5	3	6	6	11
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 69

Subject #15 (J. V.)

Male

Age, sixteen years

Angle Classification of Malocclusion, Class II, Division 1 (Figure 70)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 71): the active appliance had been removed and the patient was using a rubber finishing appliance for functional retention of the teeth.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 72):

BURSTS increased in Experiment II and remained at that level until Experiment VII where the number of bursts decreased. Experiment VIII had the same range of bursts as Experiment VII.

AMPLITUDE was moderate in the first three experiments, increased to maximum in the fourth experiment, and remained at this level through Experiment VIII.

DURATION was moderate in the first experiment, increased to maximum in Experiment II, and remained there through Experiment VII.

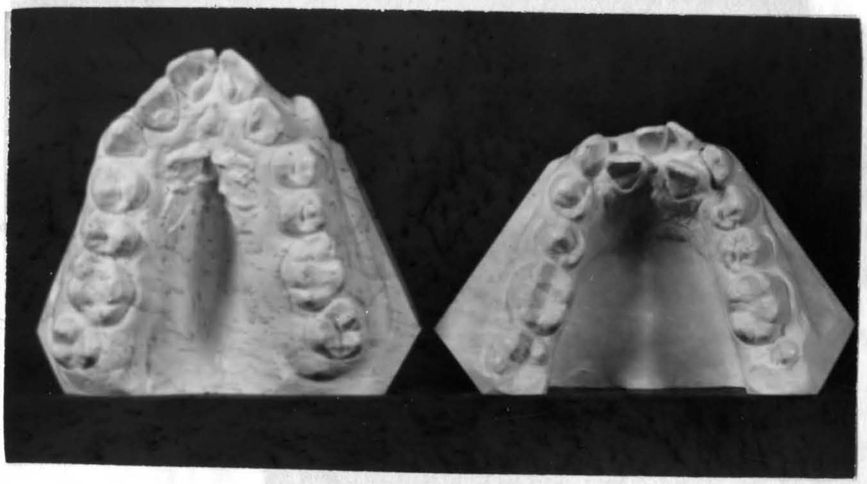


FIGURE 70

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #15

BEFORE ORTHODONTIC TREATMENT

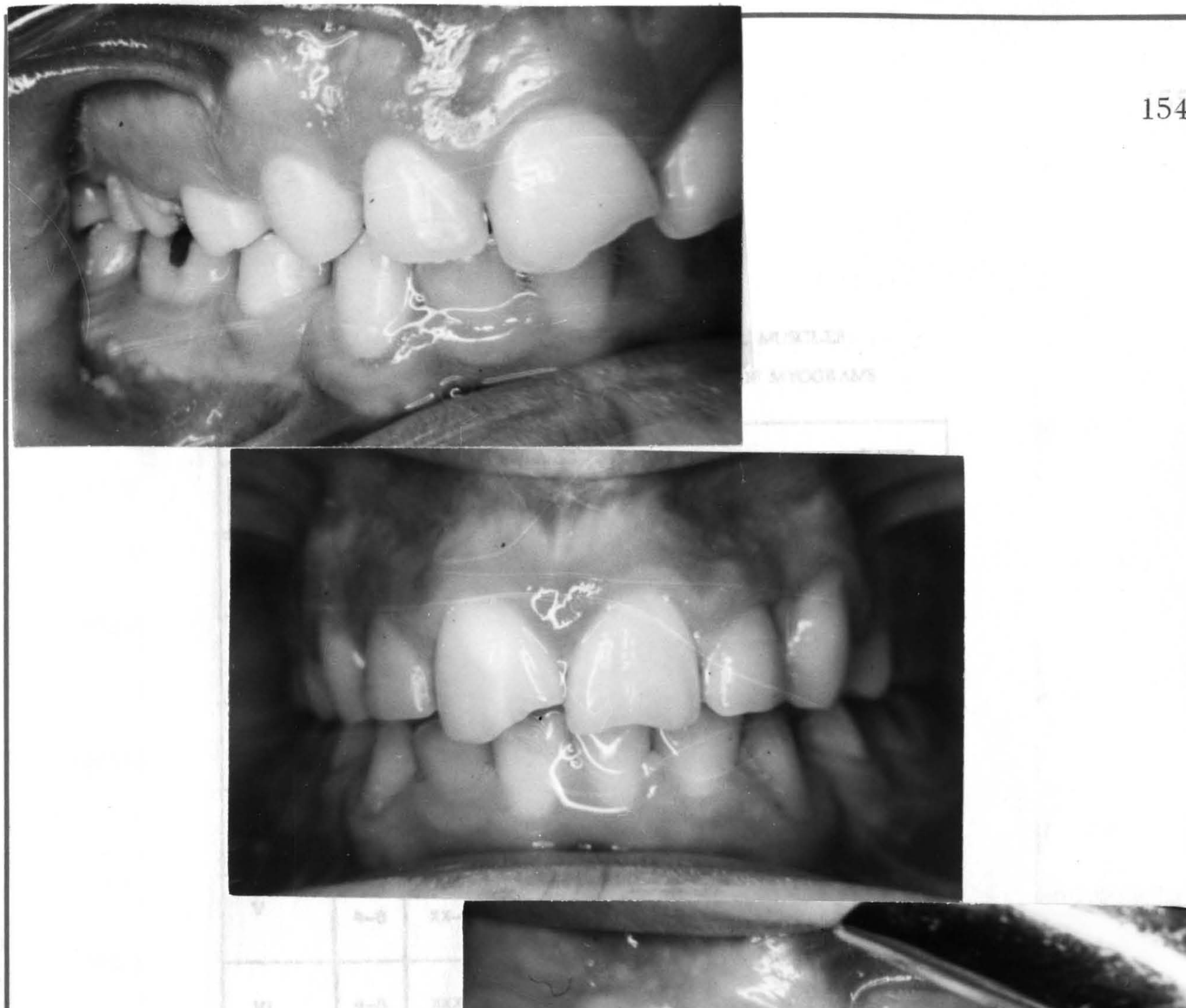


FIGURE 71

INTRAORAL PHOTOGRAPHS OF SUBJECT #15

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART I COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 15 J. V.								
Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1-6	XX	XX	XX	X-POST. TEMP.	XX	XX	X
II	4-8	XX	XXX	XXX	X	XX	XX	XX
III	4-8	XX	XXX	XXX	X-POST. TEMP.	XX	XX	X
IV	4-8	XXX	XXX	XXX	X-POST. TEMP.	XX	XX	X-XX
V	4-8	XX-XXX	XXX	XXX	X-MASS.	XX	XX	X-XX
VI	4-8	XXX	XXX	XXX	X-MASS.	XXX	XX	X-XX
VII	1-3	XXX	XXX	X-XX	X-ALL MUSCLES	X-XX	X-XX	XXX
VIII	1-3	XXX	XX-XXX	X	0	XX	XX	0

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 72

There was a slight decrease in amplitude in Experiment VIII.

NODING was moderate in Experiment I, increased to maximum in Experiment II, and continued at that level until Experiment VII where a decrease was evident. This decrease continued throughout Experiment VIII.

SUSTAINED LOW AMPLITUDE occurred in all experiments except Experiment VIII.

RATE OF ONSET was moderate in all the experiments except Experiment VI where it was maximum.

RATE OF ENDING was moderate throughout all the experiments.

INTERIM ACTIVITY was minimum in the first experiment, gradually increased to maximum by Experiment VII, and disappeared in Experiment VIII.

INITIATION OF CHEWING ACTIVITY (Figure 73) showed no change between Experiment I and Experiment VIII in the initiating of the chewing cycle by the masseter, but presented a slight increase in the synchronous initiation of chewing activity.

SUMMARY:

As treatment progressed, there was a decrease in the amount of

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 15. J. V.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	3	1	3	0	0	1	2	3
Masseter and middle temporal first	0	1	1	1	0	1	0	0
Masseter and posterior temporal first	0	0	0	0	0	0	0	0
Middle and posterior temporal first	1	4	3	1	4	6	0	0
Middle temporal first	1	0	1	0	0	0	0	0
Posterior temporal first	1	0	0	0	0	0	0	0
All together (Synchrony)	6	6	4	10	8	4	10	9
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 73

inhibition; the disappearance of both sustained low amplitude and interm activity; and a slight increase in the synchronous initiation of the chewing activity by all muscles.

Subject #16 (J. W.)

Male

Age, fourteen years

Angle Classification of Malocclusion, Class II, Division 1 (Figure 74)

Orthodontic treatment phase at the time of the electromyographic recordings (Figure 75): the active appliance had been removed and the patient was using a rubber finishing appliance for functional retention of the teeth.

Evaluation of the Characteristics of the Myograms from Experiment I through Experiment VIII (Figure 76):

BURSTS increased from Experiment I through Experiment V; decreased in the remaining experiments to a level less than in the original experiment.

AMPLITUDE was moderate in the first three experiments, maximum in the next four experiments, and returned to moderate in Experiment VIII.

DURATION increased from minimum in the first experiment to maximum in the fourth; decreased in Experiments V, VI, and VII; and

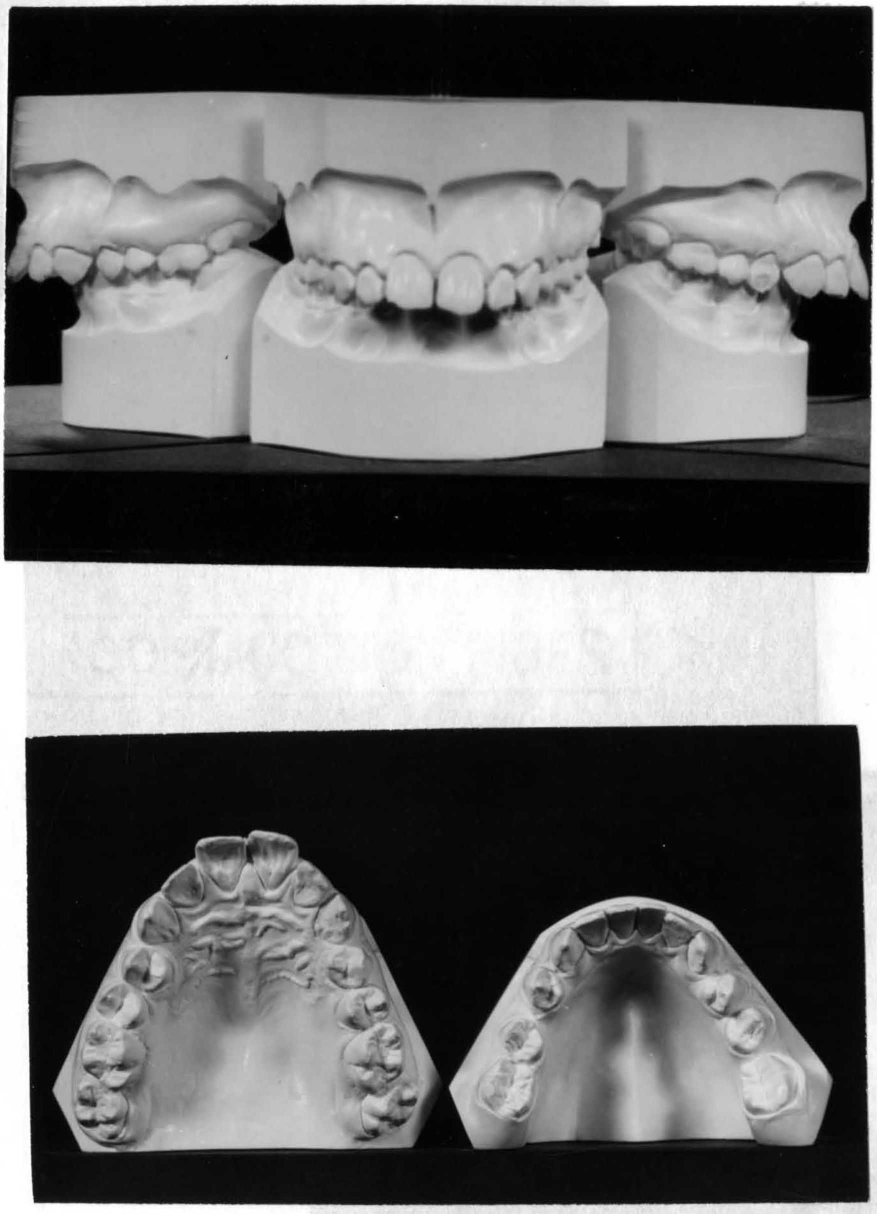


FIGURE 74

PHOTOGRAPHS OF THE PLASTER CASTS OF SUBJECT #16

BEFORE ORTHODONTIC TREATMENT

FIGURE 75

INTRAORAL PHOTOGRAPHS OF SUBJECT #16

AT THE TIME OF THE ELECTROMYOGRAPHIC RECORDINGS

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 1 COMPARISON OF THE CHARACTERISTICS OF MYOGRAMS BETWEEN EXPERIMENTS

SUBJECT NUMBER: 16 J.W.

Exp. No.	Bursts	Amplitude	Duration	Noding	Sustained low amplitude	Rate of onset	Rate of ending	Interim activity
I	1-6	XX	XX	XX	X-POST. TEMP.	XX	XX	X
II	2-8	XX	XX	XX	X	XX	XX	XX
III	2-8	XX	XXX	XXX	X-POST. TEMP.	XX	XX	X
IV	4-7	XXX	XXX	XXX	X-POST. TEMP.	XX	XX	X-XX
V	4-7	XXX	XX-XXX	XXX	X-MASS.	XX	XX	X-XX
VI	2-7	XXX	XX-XXX	XXX	X-MASS.	XXX	XX	X-XX
VII	2-7	XX-XXX	XX	XX-XXX	X	XX	XX	X-XX
VIII	1-4	XX	XXX	X-XX	X-TEMP.	X	X	X

LEGEND: xxx=maximum, xx=moderate, x=minimum, 0=no obvious change

FIGURE 76

increased again in Experiment VIII to maximum.

NODING was moderate in the first two experiments, maximum in the next four, and moderate to minimum in Experiment VIII.

SUSTAINED LOW AMPLITUDE occurred throughout the entire study.

RATE OF ONSET was moderate except for Experiment VIII where it was minimum.

RATE OF ENDING was moderate throughout the study except for Experiment VIII where it was minimum.

INTERIM ACTIVITY was moderate in the first experiment, ranged from minimum to moderate in the next six experiments, and was minimum in Experiment VIII.

INITIATION OF CHEWING ACTIVITY (Figure 77) showed as follows: no obvious change in the masseter's initiation of the chewing cycle; a large percentage of initiation by the temporals (50%); and only a slight increase in the synchronous initiation by the muscles.

SUMMARY:

As treatment progressed, there was a slight decrease in the amount of inhibition; but the other characteristics were similar to what they were in the original malocclusion. There was an increase in the initiation of

THE BEHAVIOR OF THE MASSETER AND TEMPORAL MUSCLES

CHART 2 COMPARISON OF ONSET OF ACTIVITY BETWEEN EXPERIMENTS

SUBJECT NUMBER: 16. J. W.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	1	2	0	1	0	1	1	1
Masseter and middle temporal first	1	0	1	0	1	0	0	0
Masseter and posterior temporal first	1	0	0	0	0	0	0	0
Middle and posterior temporal first	3	2	5	9	4	1	5	3
Middle temporal first	0	0	0	0	0	0	2	3
Posterior temporal first	3	4	0	0	5	1	2	1
All together (Synchrony)	3	4	6	2	2	9	2	4
TOTAL NUMBER OF CHEWING STROKES	12	12	12	12	12	12	12	12

FIGURE 77

the chewing by the temporals and only a slight increase in the synchronous initiation of chewing by all muscles.

General Summary of the Comparison of the Characteristics of the Myograms between Experiment I, Pre-Treatment and Experiment VIII, Final Stages of Treatment (viz., Chart I for each patient):

The number of bursts decreased in fourteen patients between Experiment I and Experiment VIII; and remained the same, as it was in Experiment I, for two patients in Experiment VIII.

The range of amplitude increased in seven patients and remained the same in nine patients.

The length of the duration of the chewing stroke decreased in one patient, remained the same in nine patients, and increased in six patients.

The number of nodes decreased in seven patients, remained the same in six patients, and increased in three patients.

Sustained low amplitude decreased in nine patients; remained the same in six patients for in these six patients, there was no sustained low amplitude in neither the first nor the eighth experiments; and increased in one patient.

Rate of onset of the chewing activity decreased in nine patients and remained the same in seven patients.

Interim activity decreased in thirteen patients and remained the same in three patients.

The initiation of the chewing activity for all patients (viz., Chart II for each patient) is considered in the following section.

C. Analyzing the Initiation of the Chewing Activity

The object of Part II was to ascertain any trends in the division of labor between the muscles as treatment progressed. This division of labor between the muscles was studied by examining which muscle or muscle group initiated the chewing cycle in the myogram. There were seven possible combinations in which each muscle or each muscle group was the first to function in the chewing cycle. These combinations were as follows: masseter, masseter and middle temporal, masseter and posterior temporal, middle and posterior temporal, middle temporal, posterior temporal, and synchrony-the synchronous functioning of all three muscles in initiating the chewing cycle.

All the data for the sixteen subjects for each of the eight experiments were recorded in chart form (Figure 78). These data were then plotted on a graph to give visual representation of the trend in the division of labor between the muscles as orthodontic treatment progressed.

EXPERIMENT NUMBER	I	II	III	IV	V	VI	VII	VIII
Masseter first	66	65	50	38	22	21	22	19
Masseter and middle temporal first	9	13	10	7	3	2	3	5
Masseter and posterior temporal first	5	2	10	4	0	1	5	4
Middle and posterior temporal first	19	29	37	40	48	61	25	12
Middle temporal first	3	4	6	2	6	7	5	5
Posterior temporal first	11	12	7	32	10	10	9	11
All together (Synchrony)	79	67	72	69	89	90	123	136
TOTAL NUMBER OF CHEWING STROKES	192	192	192	192	192	192	192	192

FIGURE 78

NUMBER OF TIMES A MUSCLE OR MUSCLE GROUP INITIATED THE CHEWING STROKE IN EACH EXPERIMENT

The results are shown in Figure 79.

Inspection of the graph will show that three of the muscle combinations changed very little during orthodontic treatment. These combinations are the masseter and middle temporal, masseter and posterior temporal, and the middle temporal.

The chewing cycle was initiated synchronously by all three muscles more often than any other muscle or muscle group in the first experiment, and this trend continued in the succeeding experiments. When the course of the line for synchrony in the chart is examined, it is seen that there is a vacilation in the first four experiments, the number varying as follows: Experiment I, 79 times out of a possible 192 times; Experiment II, only 67 times; Experiment III, 72 times; and Experiment IV, 69 times. The number of times synchrony, initiates the chewing cycle, beginning with Experiment V, increases at a rapid rate, finally ending with 136 times out of 192 possibilities.

The masseter was second in the number of times it initiated the chewing activity in the first experiment. During the course of orthodontic treatment, the masseter shows a marked decline between Experiment I, Before Treatment and Experiment V, During Anchorage Preparation. This

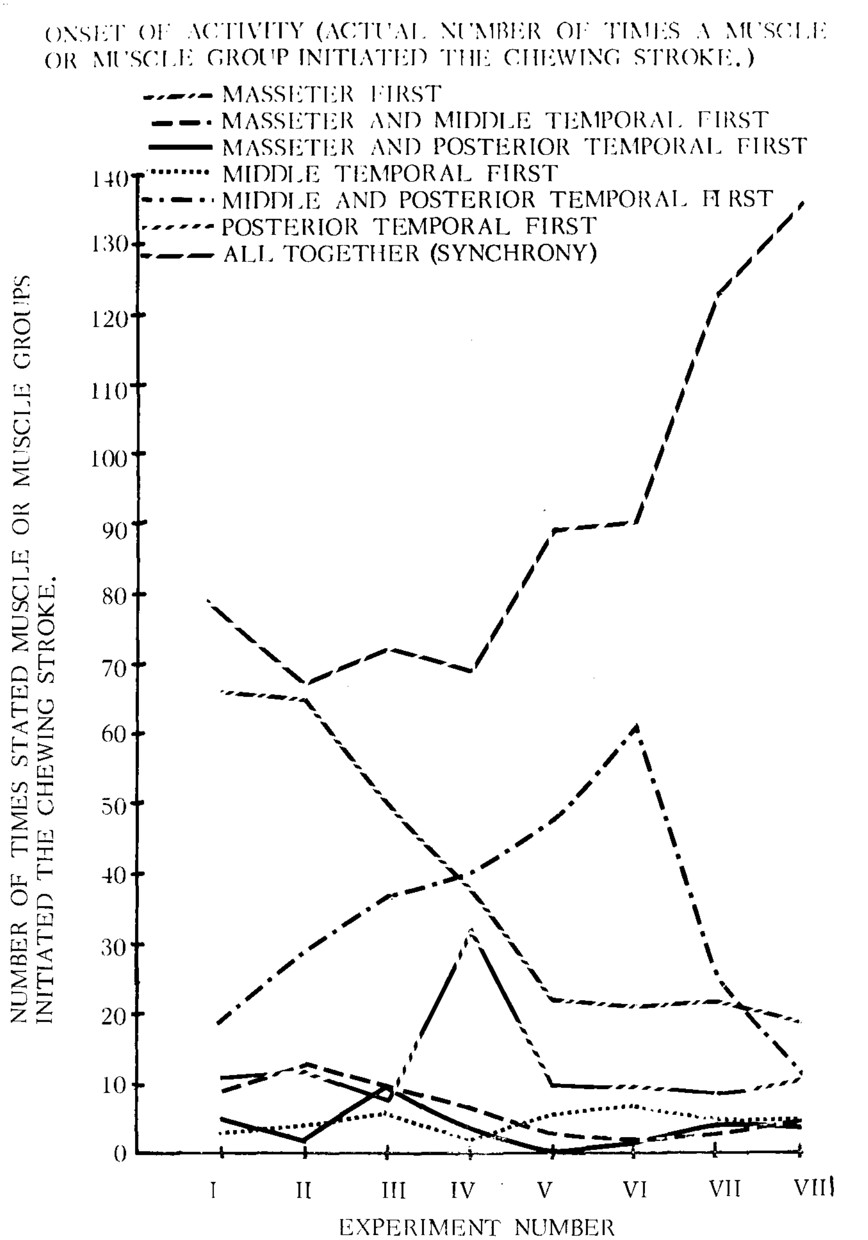

ONSET OF ACTIVITY (ACTUAL NUMBER OF TIMES A MUSCLE OR MUSCLE GROUP INITIATED THE CHEWING STROKE.)
MASSETER FIRST
MASSETER AND MIDDLE TEMPORAL FIRST
MASSETER AND POSTERIOR TEMPORAL FIRST
MIDDLE TEMPORAL FIRST
MIDDLE AND POSTERIOR TEMPORAL FIRST
POSTERIOR TEMPORAL FIRST
ALL TOGETHER (SYNCHRONY)
NUMBER OF TIMES STATED MUSCLE OR MUSCLE GROUPS INITIATED THE CHEWING STROKE.
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
I
II
III
IV
V
VI
VII
VIII
EXPERIMENT NUMBER

FIGURE 79

was a decrease from 66 to 22 times out of 192 possibilities. Experiments VI, After Completion of Anchorage Preparation, VII, During Final Stages, and VIII, During Final Stages Six Months After Experiment VII indicate a possible leveling off of the decrease in initiating chewing activity.

The middle and posterior temporal were third in the number of times they initiated chewing activity in the first experiment, with 19 times out of a possible 192 times. The data show an increase in the number of times they are first until Experiment VI, (After Completion of Anchorage Preparation). Experiment VII and VIII show a very marked decrease in the number of times these two muscle portions initiate the chewing cycle.

The posterior temporal shows slight variation in the number of times it initiates the chewing activity except during Experiment IV, One Week After Placement of the First Archwire. During this experiment, the posterior temporal initiated the chewing activity approximately three times more often than during any other phase of treatment.

It is to be noted that there is a definite trend, beginning with the placement of the first archwire, where by the initiation of the chewing cycle is a function of the synchronous action of all three muscles.

D. Measuring the Duration of the Chewing Stroke

The object of Part III was to observe what effects, if any, orthodontic treatment has on the duration of the chewing stroke. This duration of the chewing stroke was measured for each patient and then expressed as a percentage of the chewing cycle to provide for better comparison between stages of treatment as explained in "METHODS AND MATERIALS" (page 54).

In order to compare the eight experiments, the data were subjected to the Chi Square Test to determine whether there was a statistically significant difference in the duration of the chewing stroke (calculated as a percentage of the chewing cycle) in each stage of treatment (Figure 80). The data for each stage of treatment were made into a histogram to ascertain a trend.

When the data were subjected to the Chi Square Test of Significance, it was found that there was a highly significant difference at the .001% level of probability with forty-two degrees of freedom between all phases of treatment. This shows that statistically there was a significant change in the distribution of the durations of the chewing strokes

TABLE OF CHI SQUARE VALUES FOR THE FREQUENCY OF OCCURRENCES OF PERCENTAGES WITHIN CLASS INTERVALS

EXP. NO.	I	II	III	IV	V	VI	VII	VIII
CLASS INTERVAL								
0-34.9%	104.91	4.10	1.89	.58	.05	15.89	14.34	6.68
35-44.9%	5.77	16.98	3.53	.70	.18	14.86	2.32	.10
45-54.9%	17.04	10.12	18.02	3.73	.47	1.07	4.63	6.23
55-64.9%	14.12	8.39	14.93	3.09	.39	.89	3.84	5.17
65-74.9%	.08	2.23	2.47	.38	3.53	4.26	4.26	4.26
75-84.9%	6.53	.94	5.75	.72	2.89	3.03	1.59	11.81
85-100%	2.60	5.24	.03	66.80	1.06	6.17	5.73	22.42
TOTAL	151.05	48.00	46.62	76.00	8.65	46.17	36.71	56.70

TOTAL $CHI^2 = 478.90^{***}$

WITH 42 DEGREES OF FREEDOM

THE ASTERISKS CORRESPOND TO THE LEVEL OF SIGNIFICANCE AS FOLLOWS: * TO 5%; ** TO 1%; *** TO 0.1%.

FIGURE 80

between all the phases of treatment.

The data from Experiment VIII were then compared individually with the data of Experiment I, Before Treatment, and Experiment VII, The Final Stages, Six Months Previous to Experiment VIII, to determine what change had occurred between these experiments. Both comparisons showed a highly significant difference at the .001 per cent level of probability with six degrees of freedom, indicating that there is no similarity in the distribution of the duration of the chewing strokes (expressed as a percentage of the chewing cycle) in these phases of treatment.

To facilitate a method for grouping the data, percentage intervals (hereafter called class intervals) were arbitrarily designated. The number of times the duration of the chewing stroke will fall within a class interval was called the frequency of occurrence; and this frequency of occurrence, within each class interval, was plotted for each experiment. There is one histogram for each phase of treatment in which electromyograms were taken in this study; and they are arranged in sequence in Figure 81 and Figure 82.

Comparison of the number of times the length of the duration fell

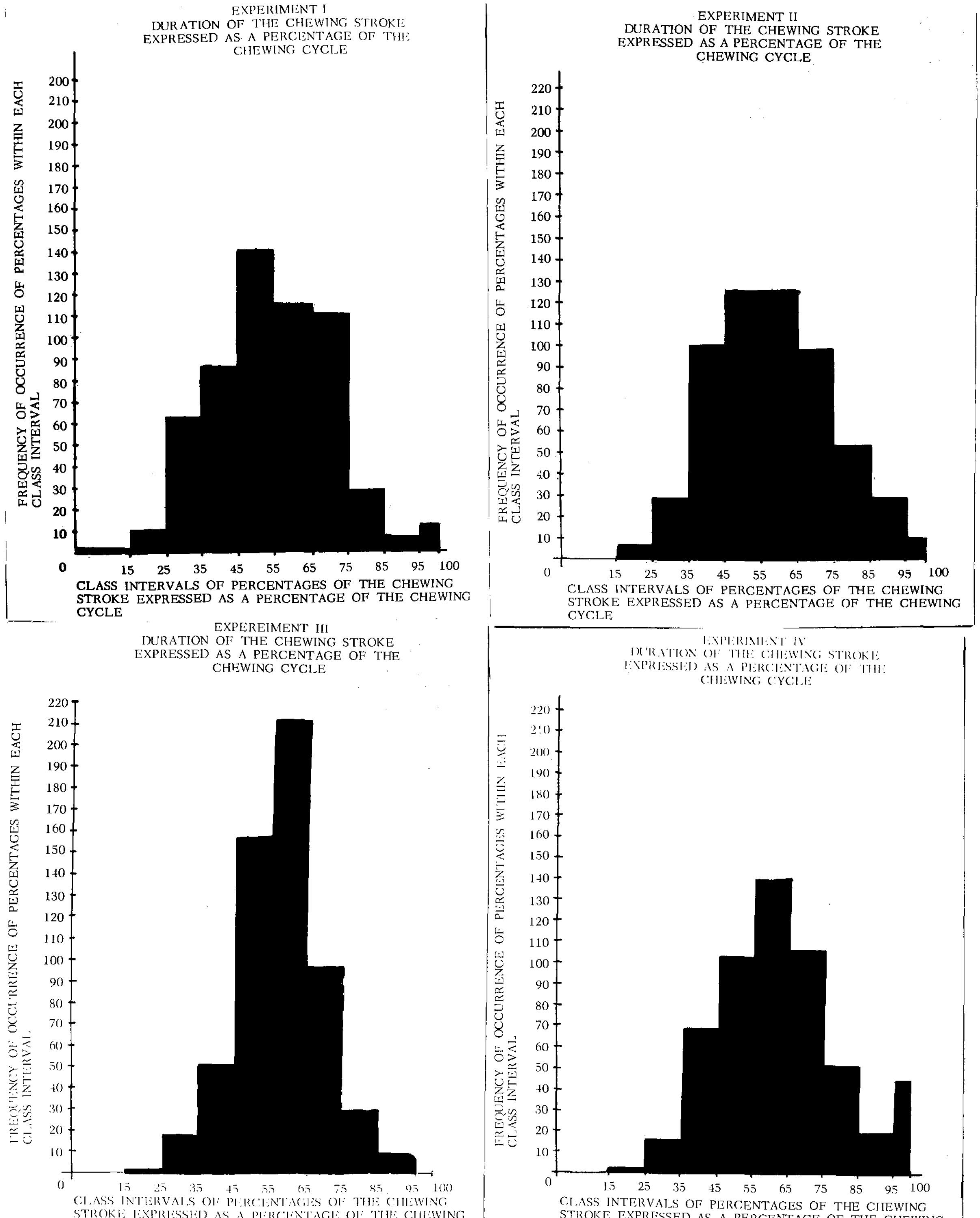
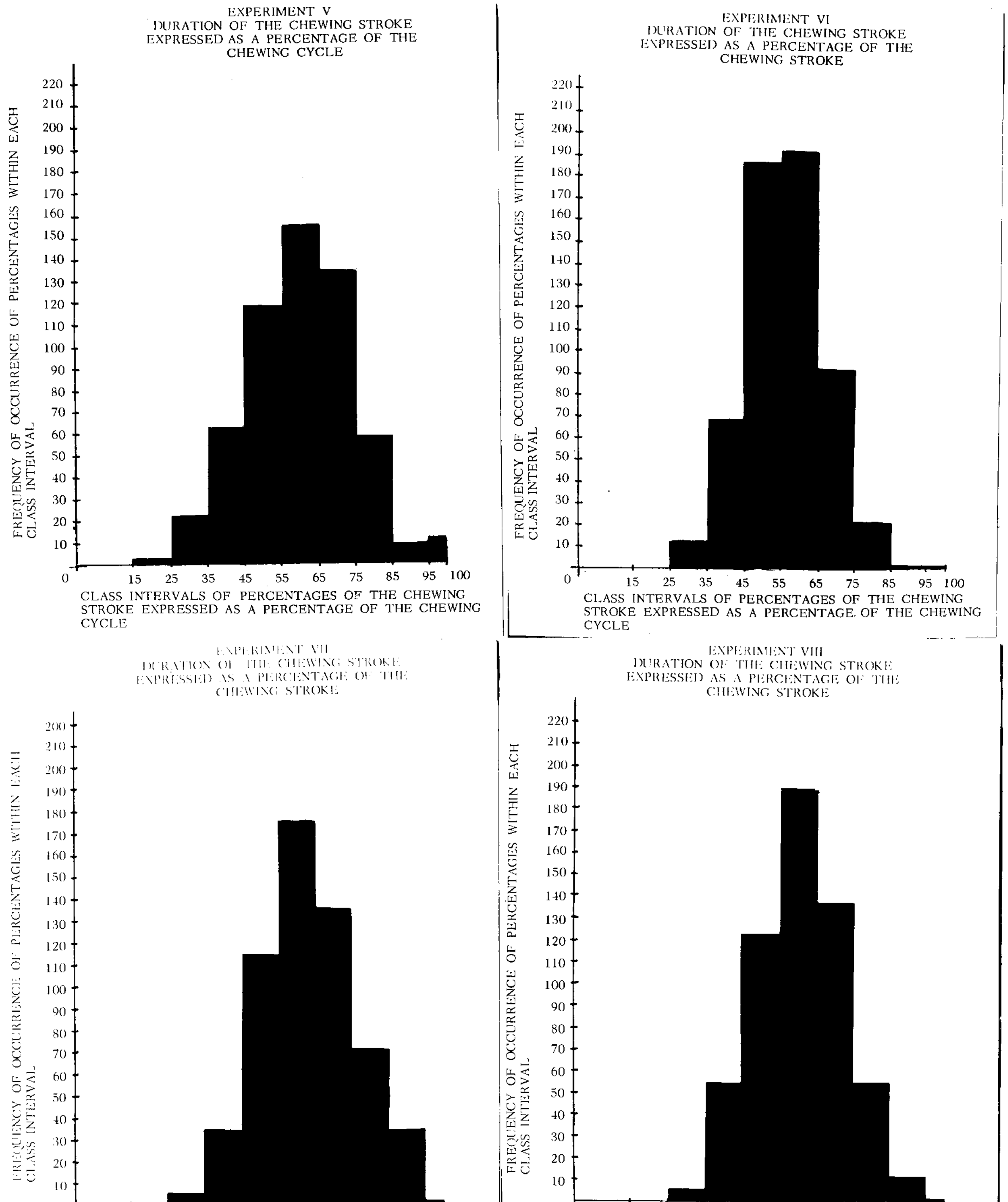

EXPERIMENT I
DURATION OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
EXPERIMENT II
DURATION OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
EXPEREIMENT III
DURATION OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
EXPERIMENT IV
DURATION OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
0 15 25 35 45 55 65 75 85 95 100

FIGURE 81



EXPERIMENT V
DURATION OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
EXPERIMENT VI
DURATION OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING STROKE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
EXPERIMENT VII
DURATION OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING STROKE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE
EXPERIMENT VIII
DURATION OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING STROKE
FREQUENCY OF OCCURRENCE OF PERCENTAGES WITHIN EACH CLASS INTERVAL
CLASS INTERVALS OF PERCENTAGES OF THE CHEWING STROKE EXPRESSED AS A PERCENTAGE OF THE CHEWING CYCLE

FIGURE 82

within a class interval shows the following changes: 1) a decrease in the class intervals of 0% to 24.9% and 95% to 100%; 2) an increase in the class intervals between 45% and 74.9%; 3) a variation from one experiment to the next, without forming any definite trend, within the class intervals of 35% to 44.9% and 75% to 94.9%.

In general terms, the extreme high and low lengths of the duration of the chewing stroke decreased, the middle range increased, and those class intervals on either side of the middle range did not change.

E. Part IV Analyzing the Number of Bursts Per Chewing Stroke

The object of Part IV was to determine whether there was a statistically significant difference between the inhibition occurring in the muscles of those patients wearing appliances and, of those not wearing appliances. Fleming (1961) in Experiment VI of this longitudinal study (Completion of Anchorage Preparation) concluded that the number of bursts in a chewing stroke was a reasonably good electromyographical indicator of the number of times inhibition had taken place in the muscles. Thus, analyzing the number of bursts in a chewing stroke would also indicate whether there was a statistically significant difference between the two groups regarding the number of times inhibition occurred.

The data, as explained on page 55 of "METHODS AND MATERIALS", are a random sample of one third of all that was collected. Since the values obtained were counts and do not follow the normal distribution, these data cannot be used in an analysis of variance and were transformed before being subjected to the analysis of variance. The transformation used was the square root of the observation plus one. A sample from the data sheet (showing two subjects) is presented in Figure 83 to show the method by which the different main effects were tabulated.

There were three main effects and three interactions considered in setting up the analysis of variance table Figure 84. The three main effects were as follows: between the appliances (those subjects wearing appliances and those not wearing appliances); between sides (subjects' right and left sides); between muscles (the masseter, the posterior temporal, and the middle temporal). The three interactions were as follows: the effect of the appliances on the sides, the effect of the appliances on the muscles, and the effect of the sides on the muscles. The error term used was the sum of the sums of squares of the residual sources of error (the residue) and the sums of squares of the duplicates. These

FIGURE 83

SAMPLE DATA SHEET FOR ONE EXPERIMENT
SHOWING TRANSFORMED DATA FOR ONLY TWO SUBJECTS

THE TRANSFORMATION USED WAS THE SQUARE ROOT OF THE OBSERVATION PLUS ONE (1).
THE OBSERVATIONS CONSISTED OF RANDOM SAMPLES FROM THE TOTAL DATA OF THE NUMBER OF BURSTS IN A CHEWING STROKE.

WITH APPLIANCES

SIDES		RIGHT			LEFT		
MUSCLES		POST. TEMP.	MID. TEMP.	MASS.	POST. TEMP.	MID. TEMP	MASS.
SUBJ.	DUP. SUM DIFF.						
SUBJECT NO. 9 C. R.	A	1.73	1.73	1.73	1.41	1.41	1.41
	B	1.73	2.24	1.73	1.41	1.41	1.41
	SUM	3.46	3.97	3.46	2.82	2.82	2.82
	DIFF.	0	-.51	0	0	0	0

WITHOUT APPLIANCES

SIDES		RIGHT			LEFT		
MUSCLES		POST. TEMP.	MID. TEMP.	MASS.	POST. TEMP.	MID. TEMP.	MASS.
SUBJ.	DUP. SUM. DIFF.						
SUBJECT NO. 10 H. S.	A	1.41	1.73	1.73	1.73	1.73	1.73
	B	1.73	1.41	1.73	2.24	1.73	2.
	SUM	3.14	3.14	3.46	3.97	3.46	3.73
	DIFF.	-.32	.32	0	-.51	0	-.27

ANALYSIS OF VARIANCE TABLE

SOURCES OF VARIATION	DEGREES OF FREEDOM	SUMS OF SQUARES	MEAN SQUARE	F
APPLIANCES	1	.54	.54	12.73***
SIDES	1	.02	.02	.471
MUSCLES	2	.81	.42	9.91***
SUBJECTS WITHIN APPLIANCES	14	3.94	.281	6.63***
A x S	1	.54	.54	12.73***
A x M	2	.27	.135	3.183*
S x M	2	.11	.055	1.30
RESIDUE	72	1.91	$\frac{7.12}{168} = .054$	
DUPLICATES	96	5.21		
TOTAL	191	13.35		

THE ASTERISKS CORRESPOND TO THE LEVEL OF SIGNIFICANCE AS FOLLOWS: * TO 5%; ** TO 1%; *** TO 0.1%.

FIGURE 84

were summed because both were sources of error in the experiment; and neither was significantly large to be used alone for the error term, to be compared with the main effects and the interactions in order to obtain the respective F value (the variance ratio) for each source of variation.

The result of the analysis of variance show that in the three main effects studied there was a highly significant difference between appliances and between muscles, both having F values greater than the .001 per cent level of probability. The F value for the source of variation between sides was not significant. The variance ratio for subjects within the two groups was highly significant at the .001 per cent level of probability. Of the three interactions studied, the effect of the appliances on the sides was highly significant at the .001 per cent level of probability; the effect of appliances on muscles was significant at the .05 per cent level of probability; and the effect of sides on muscles was not significant.

CHAPTER IV

DISCUSSION

A. General Considerations

Living structure, of which muscle tissue is one, has three modalities: excitation, conduction, and motion. The part which the sensory stimuli from the periodontal ligament play in the reflex arc influencing the motor behavior of the temporal and masseter muscles is the subject of this thesis. More specifically, this thesis deals with the modification of the sensory input from the teeth in moving these teeth orthodontically from a malocclusion to normal occlusion.

In this investigation, electromyography was the method by which the interaction of the muscles and the nerves--the neuromuscular mechanism governing mandibular movement--was studied to observe what changes occurred in muscular behavior during orthodontic treatment.

The modus operandi of the neuromuscular mechanism of mastication is that any stimulus to the mechanism may cause a reflex reaction, and this reaction is a change in the behavior of the muscles. For example, when one bites into a hard object such as a cough drop, at the moment the cough drop breaks the teeth will not meet with sufficient impact to crack the enamel of the teeth. Also, if there is an interference in the interdigitation of the teeth, the muscles, reflexively, close the jaw in such a manner that the harmful effect of the interference tends to be minimized. It is by means of two reflex arcs, one through the mesencephalic root of the trigeminal nerve--which mediates proprioception and pressure--and the other through the spinal nucleus of the trigeminal nerve--which mediates pain--that the motor output to the muscles of mastication is altered by the sensory input of the periodontal ligament.

As the result of the work of Dependorf (1913), Kadanoff (1929), Lewinsky and Stewart (1937), Van der Sprenkel (1936), Bernick (1957), and Rapp (1957), it is known that the nerve endings in the periodontal ligament transmit the modalities of proprioception, pressure, and pain. It is the special end organs of the nerves of the periodontal ligament that distinguish these modalities.

The end organs for pressure and proprioception in the periodontal ligament, along with special nerve endings in the muscles (the neuromuscular spindle), in the tendons (the Golgi tendon organs), and in the capsule of the temporomandibular joint (the Pacinian corpuscles), are all sensory afferent transmitting organs whose stimuli are transmitted along the trigeminal nerve to the mesencephalic root. When these afferent impulses reach the mesencephalic root, they follow one of two pathways.

The first pathway from the teeth forms a two-neuron reflex arc through the mesencephalic root to the motor ganglion cells of the masticatory muscles. According to Corbin (1940), the impulses from the motor ganglion cells to the muscles are inhibitory; that is, the magnitude of the force of muscular contraction is lessened. The result of this decrease in muscular contraction is a decrease in the biting force or else a change in the movement of the mandible in closing. The net effect of the two-neuron reflex arc is the protection of the teeth and their supporting structures.

The second pathway goes into the cerebellum, and then through the thalamus to the cortex where the afferent impulse is recognized on a conscious level.

The impulse of pain is transmitted to the spinal nucleus of the trigeminal nerve and then relayed to the cerebral cortex. The indication is that when pain becomes involved in the operation of mastication, muscular contraction is on a more conscious level than reflex level (Zylinski, 1961).

B. Review of the Longitudinal Study

Electromyographic recordings of the masseter and temporal muscles were taken on sixteen patients presenting varying malocclusions. The myograms were taken before the orthodontic treatment was started and during various stages of treatment. During each treatment stage, the first three chewing strokes of two chewing exercises of the right and left masseter and temporal muscles were electromyographically recorded. These myograms were compared to myograms from previous treatment stages rather than with myograms from a control group of people with normal occlusion because it was the object of this study to investigate only the changes in the myogram that occurred during the course of orthodontic treatment.

In Experiment I, Widen (1960) recorded the muscular activity as displayed by the patients before any treatment was begun. This muscular activity of the original malocclusion served as a basis for comparison as orthodontic treatment progressed. In Experiment II, Widen (1960) studied the change in muscular activity one day after placement of separating wires between the teeth (used in order to separate the teeth before placing metal bands around them). During the time when the brass wires were in place, the teeth were forced to move in every direction to gain space--buccally, lingually, labially, or occlusally. Widen found a definite change in behavior patterns of the masseter and temporal muscles and an increase in the length of the duration of the chewing stroke for seven of the sixteen patients.

In Experiment III, Asahino (1960) studied the change in muscular activity seven days after placement of separating wires between the teeth. He found that there was little change in muscular activity when compared to pretreatment studies; and he concluded that this was due to adaptation on the part of the neuromuscular mechanism.

In Experiment IV, Shanahan (1960) studied the change in muscular activity seven days after the placement of the first archwire. During the time between Experiment IV and the previous experiment, the separating wires were removed and bands cemented on the teeth. After the bands were cemented, the first archwires were placed. These archwires began the movement of teeth to the desired positions and changed the axial inclinations of the teeth. As a result of the change in the axial inclinations of the teeth, there was a change in the occlusal interdigitation of the opposing teeth in the jaws.

Shanahan found the following changes in muscular behavior when compared to the pretreatment records of the masseter and temporal muscles: an increase in the length of the duration of the chewing stroke; an increase in the number of times the posterior fibers of the temporal muscles initiated the chewing cycle; and a decrease in the number of times that the masseter initiated the chewing cycle. He attributed these changes to the modification of proprioceptive stimuli from the periodontium. These findings indicated that the patients were using more caution in chewing, since they took longer to chew, as evidenced by the longer duration of the chewing stroke and the increased number of bursts indicating inhibition during the chewing cycle. The decrease in the number of times the masseter began the chewing cycle is due to the fact that the masseter is a power muscle whose great force is not utilized by the cautious chewer.

In Experiment V, Zylinski (1961), studied the change in muscular activity six to eight weeks after the placement of the first archwires. Zylinski and Fleming (1961) also reappraised the findings of the previous investigators. This reappraisal showed that statistically the greatest number of bursts up to that time occurred in Experiment III, indicating a great amount of inhibition. Zylinski, said that the changes could be attributed to the traumatic nature of the placement of the separating wires, since pain takes precedence over proprioception in the "final common pathway"; the inhibition that occurred was the result of pain rather than tooth movement.

During the intervening time between Experiment V and the previous experiment, the posterior teeth were being uprighted and the alignment and position of the anterior teeth were changed. When Zylinski compared his findings to those of pretreatment records, he found that there was a small increase in the number of bursts; a definite increase in the length of duration of the chewing stroke; and a marked increase in occurrence in the synchronous initiation of the chewing stroke by the muscles studied. He concluded that pain is more important than proprioception in causing the changes in the behavior of the masseter and temporal muscles. He affirmed that there was a change in the division of labor between the masseter and temporal muscles, the temporals becoming more active and the masseters becoming less active, as treatment progressed, in the initiaton of chewing activity.

In Experiment VI, Fleming (1961) studied the change in muscular activity after the appliances had been on the teeth twelve to sixteen weeks. During the time interval between Experiment V and VI, the mandibular posterior teeth had been uprighted and tipped distally from their original positions. The maxillary posterior teeth were tipped distally five degrees from the vertical and the mandibular posterior teeth were tipped eight degrees from the vertical. The object of this distal tipping was to open the occlusal vertical dimension. His findings, when compared to the pretreatment study, showed a decrease in the number of times the masseter initiated the chewing cycle, and an increase in the number of times the middle and posterior temporal muscle portions initiated this cycle. There was also an increase in the duration of the chewing stroke. He then compared his findings to those of Experiment V and found a decrease in the number of times there was a synchronous initiation of the chewing cycle by the muscles studied. These changes he attributed to the distal tipping of the previously uprighted posterior teeth and to the painful experiences during mastication. He further concluded that the number of bursts in a chewing stroke is a reasonable indication of the number of times inhibition has taken place in the muscles being studied.

In Experiment VII, Roth (1962) studied the change in the muscular activity during the final stages of treatment. During the time interval between Experiment VII and Experiment VI, the molar relationship was being corrected; the alignment and closing of spaces between the teeth was being completed; and, in four cases, the bands had been removed. As a result, this experiment differed from the previous experiments in that the patients were not all at the same level of treatment. He compared his findings with all the other stages of treatment and found that during any treatment stage, where the long axes of the teeth were not parallel to the forces of occlusion or where there were occlusal interferences, there was greater inhibition exhibited by the temporal and masseter muscles in mastication. After the Class II molar relation was corrected, he also found that the muscular behavioral pattern of activity showed a marked improvement during the final stage of orthodontic treatment. He advanced the ideas that there may well be an habitual length for the chewing stroke, and that there is a decrease in the amount of inhibition in the temporal and masseter muscles after orthodontic appliances are removed.

In this part, Experiment VIII (Part VII of the whole investigation), the change in muscular activity was studied in the final stages of treatment. In the six months that had elapsed between this study and Experiment VII, five more patients completed the active phase of orthodontic treatment and the bands were removed, thus making a total of nine patients in this experiment not wearing bands. The other seven patients were progressing in their treatment to where their appliances would probably be removed within the next six months. Of the seven patients wearing appliances, three were having the Class II molar relation corrected; three were at the stage of space consolidation between the anterior teeth; and one was having the midline of the maxillary teeth corrected to that of the midline of the mandibular teeth. In each of these stages, teeth were being moved to different positions; and since the sensory input changed as a result of changes in the occlusal relations and the axial inclinations of the teeth, these changes in occlusion will be described.

In the correction of the Class II relationship of the molars, the maxillary posterior buccal segment is moved distally; and there may or may not be a mesial movement of the mandibular posterior buccal segment. For this movement of teeth to occur, the incline planes of the cusps of the maxillary teeth must slide up one side of the apposing cusps and then slide down the opposite side of the cusp before a correct interdigitation occurs. During this stage of tooth movement, occlusal interference would be expected because the teeth tend to occlude unevenly and possibly the molar teeth are the only teeth in occlusion. Occlusal interference should continuously decrease as the teeth move toward the desired positions. Natural attrition of small interfering areas should, in time, eliminate any cuspal interference. If this attrition does not occur, then equilibration must be attempted to eliminate the cuspal interference.

Space consolidation and midline correction is begun after the Class II molar relation is corrected. As a result, there is little or no interference in the apposition of the teeth in chewing. During this time, because of the forces of occlusion, the posterior teeth gain a better appositional relation than in previous stages. According to Zylinski (1961), because of the elimination of most occlusal interferences and therefore pain, mastication is more under the control of the reflex action rather than under conscious control.

When the bands are removed, the incline planes of the cusps of the teeth are in correct occlusal relation of incline plane to incline plane, but not necessarily in optimal occlusal apposition. One of the purposes of orthodontic treatment is to place the teeth in optimal occlusal relation of incline plane to opposing incline plane. Therefore, the patients were instructed to wear a functional finishing appliance. These are made of a light resilient rubber and create a gentle force when the patient bites into the rubber. This force helps guide the occlusal surfaces of the teeth into an optimal position. As the teeth obtain their optimal cusp and incline plane relation, it is reasonable to assume that the myograms would show a change in the muscular behavior when compared to the pretreatment myograms.

C. Interpretation and Evaluation of the Findings

1. Listing and Evaluating the Characteristics of the Myograms of the Individuals

The object of this method of study was to observe the changes in the electromyographic behavior of the muscles for each individual during the various stages of orthodontic treatment and to observe the general trends, if any, which would evolve. If these trends were ascertainable and the exceptions to these trends understood, a better understanding of the nature of the effects of the occlusion on the muscles that move the mandible would follow.

The characteristics of the myograms used in this study describe the myograms and give a clue on the action of the muscles as treatment progressed.

Bursts and noding are both a measure of the inhibition in the muscles. The greater the number of bursts and nodes, the greater the inhibition of the muscles. In relation to occlusion, cuspal interference or pain would cause inhibition; and thus, conversely, bursts and noding are indicators of either cuspal interference or pain or both.

Gasser (according to Fulton, 1955), described inhibition as follows:

> Inhibition is a term of convenience used without exact definition in connection with a group of phenomena having certain qualities in common. The essential condition is the stoppage or prevention of action through the temporary operation of a process which does not harm the tissue. It is usually implied that the process results from nervous activity, or imitates the result of nervous activity.

Inhibition as used in this thesis refers to the transitory partial arresting of the chewing action as shown by the number of bursts on the myograms. This transitory arresting of the chewing action can be compared to a braking action which causes a moving vehicle to slow down but not necessarily to stop. During the chewing of the cough drop, there were transitory interruptions of the biting strokes but not complete stoppages. It is in this sense of partial interruption of the biting action that the term inhibition is used in this thesis.

Amplitude is an indication of the magnitude of the force used in biting through the cough drop. It was not used as a quantitative measure because too many variables exist.

The rate of onset and the rate of ending of the myogram indicated the type of chewing stroke used by the patient. Pruzansky (1952) showed that the short ballistic type of chewing stroke with a rapid build-up and rapid decline was characteristic of occlusion with interference in the cuspid region, which prevented lateral excursions. This ballistic type of chewing is characteristic of a chopping bite.

Duration of the chewing stroke is an indication of the amount of time the subject was actively closing his jaws.

Interim activity is an indication of imbalance in the opening of the jaws, requiring either the masseter or temporal muscles or both sets of muscles to contract in order to stabilize the jaw during opening (MacDougall and Andrew).

Sustained low amplitude is an indication of spasmodic activity in the muscles and implied interference in occlusion.

Inhibition--as shown by the number of bursts of electrical activity--and the synchronous initiation of the chewing stroke gave the best indications of the behavioral change in the muscles.

From the beginning of this study and through the stage when the first archwires were placed, the patients showed great inhibition as compared to the muscular behavior before treatment was begun. There was also a decrease in the synchronous initiation of chewing activity; the greatest change in muscular behavior occurred one week after the placement of the first archwire. According to Graber (1961), "The relations of the teeth to each other within each arch and with apposing members are the result of the morphogenetic pattern, as modified by the stabilizing and active functional duties of the muscles." Thus, at the beginning of the malocclusion, the position of the teeth were in equilibrium with the muscles, the temporomandibular joint, and the apposing teeth. When the teeth were moved orthodontically from their original position, this equilibrium was interrupted and sensory impulses from the periodontal ligament caused an altered muscular behavior--

cautious chewing as shown by the increase in inhibition. This inhibition was identified with increase in the number of bursts and nodes.

During the time when the posterior teeth were uprighted in preparing anchorage, the teeth came into a more favorable alignment and the electromyograms showed less inhibition and more synchrony in the initiation of the chewing activity. Also, a slight increase in the amplitude of the chewing activity was observed. These axial and occlusal changes in the position of the teeth, as shown by Jarabak (1954), Widen (1960), Asahino (1960), Shanahan (1960), Zylinski (1961), Fleming (1961), and Roth (1962), and others, altered the input of the sensory receptors (proprioception, touch, and pain) in the periodontal ligament; these regulate, in a large measure, the motor behavior of the temporal and masseter muscles. These axial and occlusal changes in the teeth would account for the reactions in the electromyographic behavior of the muscles as orthodontic treatment progressed.

When the teeth were distally tipped in anchorage preparation, the muscular behavioral pattern became less favorable as shown by an increase in inhibition. It was at this stage in treatment that posterior teeth of the maxilla and the mandible were occluding in and edge to edge manner; and, in many instances, the molars were the only teeth in contact. These teeth in many cases were tender, indicating pain during mastication. As explained previously, pain would tend to bring the muscles under a more conscious level than reflex level of operation.

In the final stages of treatment, Roth (1962), showed that when the Class II molar relation had been corrected, there was a decrease in inhibition and an increase in the synchronous initiation of the chewing activity. This again indicated that the teeth were returning to a more favorable axial and incline plane relation of the teeth. He listed two exceptions to this trend which will be discussed shortly.

Generally speaking, between Experiments I and VIII, there was a marked decrease in the number of bursts and the interim activity, indicating that the teeth were encountering less interference in the final stages of treatment than they were in the pretreatment stage.

The greatest imporvement was shown in the nine patients in which the appliances had been removed. The range of bursts (indicating inhibition of the muscles) decreased; the interim activity of the muscles decreased or was nil; and synchronous initiation of the chewing activity was by far the most dominant manner of initiating the chewing activity.

In Experiment VIII, in two cases, (subjects number 12 and 16), when the active appliances were removed, the previous generalization did not occur. Subject number sixteen was also an exception in Experiment VII. The other exception in Experiment VII, subject number eight, showed an excellent muscular behavioral pattern in Experiment VIII. This would imply that having this subject wear a functional finishing appliance, together with the application of the normal forces of occlusion when the appliance was not in place, brought an harmonious axial inclination and cuspal incline relation of the subject's teeth. This change in occlusion was indicated by the change in the myogram.

Subject number twelve showed a decrease in the synchronous initiating of the chewing cycle as compared to Experiment VII. Examination of the photographs show that the interdigitation of the molars on both sides was not completed and there was, therefore, an interference in the occlusion.

Subject number sixteen exhibited less inhibition and noding, and a more increased synchronous initiation of chewing activity in Experiment VIII than in Experiment VII; but not as favorable a muscular behavior as in Experiment VI. When his occlusion is considered, it should be noted that the mandibular first molars are missing. These had been removed before he presented himself for treatment. The plan of orthodontic treatment called for extraction of the maxillary right and left first bicuspids to balance out the occlusion relative to tooth material. It is possible that, because of the resulting interdigitation of the remaining teeth, there are occlusal interferences.

Both of these subjects (number twelve and sixteen) should have their teeth equilibrated before the next papers that follow in this study are presented. It will be interesting to note whether the muscular behavior will show an harmonious distribution of labor between the muscles as was found in the seven other treated cases.

2. Analyzing the Initiation of the Chewing Activity by the Various Muscles

The object of this part of the investigation was to ascertain if there were any differences in the division of labor between the temporal and masseter muscles as treatment progressed. All the possible combinations of muscles were considered. From Experiment I through Experiment VI, there was an increase in the number of times the middle and posterior temporal muscles, acting in combination, initiated the chewing cycle. In Experiment VII this upward trend reversed itself and decreased sharply through Experiment VIII.

It is to be noted that, although the masseter, the middle temporal and the posterior temporal muscles individually showed a decrease in the number of times each initiated the chewing cycle, all three are a part of the synchrony which increased.

The function of the masseter and temporal muscles must be considered collectively in order to understand what was taking place as treatment progressed. Sicher describes the temporal muscles as "positioners" of the mandible, whereas the masseters provide the power for the masticatory stroke.

Moyers (1950) showed that in Class II, Division I malocclusions the masseter initiated the chewing stroke. In this study, most of the malocclusions presented were a Class II, Division I malocclusion; and, at the beginning of the study, the masseter was second only to synchrony in the number of times that it initiated the chewing cycle. As the malocclusions were treated, the number of times the masseter initiated the chewing cycle by itself decreased. This is logical because, during the changing of the occlusal relations of the teeth during orthodontic procedures, the teeth do not occlude in a normal relation and may be painful. In such a case a power muscle would not be used and a closing muscle, the temporal muscle, with not as great a force as was customary prior to treatment would close the jaws. In this study it was found that the middle and posterior temporal (in combination) increased in the number of times that they initiated the chewing stroke until the final stages of treatment occurred. As the teeth occluded in a more normal relation, the temporal decreased in the number of times it initiated the chewing stroke. There was an increase in the occurrence of synchronous initiation of the chewing activity, and since this was concurrent action of both temporal and masseter, it is apparent that there is a more equal distribution of labor between the muscles in this stage of treatment.

The use of the masseter, or lack of its use in the initiating of the chewing cycle, can best be explained in terms of the neuromuscular mechanism of mastication. The masseter came into use when the axial inclinations and incline plane relations of the teeth were such that the forces of occlusion were parallel to the long axes of the teeth. When these relations occurred, impulses were sent from the sensory receptors in the periodontal ligament to the mesencephalic root of the trigeminal nerve which reflexively controlled mastication by efferent impulses to the masseter and temporal muscles. Whenever occlusal interferences were present, that is, when the axial inclination and incline plane relation of the teeth were such that the forces of occlusion were not parallel to the long axes of the teeth, chewing on a hard substance, such as a cough drop, probably stimulated the pain receptors in the periodontal membrane. These pain impulses, mediated by the spinal nucleus of the trigeminal nerve and correlated with other afferent impulses in the posterior central gyrus of the cerebral cortex, caused the trigeminal motor nucleus to alter the efferent impulses to the masseter and temporal muscles. In this manner the neuromuscular system prevented additional painful stimuli. A similar inhibitory mechanism operated over the two-neuron reflex arc, mediated by the mesencephalic root of the trigeminal nerve. Over these two nerve pathways for pain and proprioception, the resulting efferent stimuli to the masseter and temporal muscles change their magnitude of contraction and thus protect the teeth and surrounding structures from damage (Corbin, 1940; Szentagothai, 1949).

Moyers (1950) found that in the Class II, Division I type of malocclusion the masseters initiated the chewing activity more often than the middle and posterior fibers of the temporals. This finding was found to be consistent with that of the first part of this study when Widen (1960) showed that the masseters were second only to the synchronous initiation of chewing activity by all three pairs of muscles. An interesting question is raised as to why the masseters should initiate chewing activity in a malocclusion when interferences present in the occlusion would call for a "guiding" action by the temporal muscles rather than a "power" functioning by the masseters (Sicher, 1960).

Part of the answer may be provided by Randall (1962) in his book on the Elements of Biophysics. He states as follows:

> Appreciation of the vector nature of mechanical forces is important in considering the force that a muscle must develop when it is at an unfavorable angle in relation to a bone. When a muscle exerts a force upon a bone, only the component of the force vector which is perpendicular to the bone is effective in the movement of the bone around its axis. Similarily, the work done is defined as the product of the displacement and the component of the force in the direction of the displacement. Therefore, the actual magnitude of the force by itself carries very little meaning without knowledge of the direction.

The masseter (and for that matter all muscles of mastication) close the jaw through the rotation of the mandibular condyle within the glenoid fossa. In the Class II, Division I malocclusion there tends to be a distal displacement of the jaw; and the muscles of mastication could be at "an unfavorable angle in relation to the bone". Conceivable, it would require a greater magnitude of force to obtain a vectorial resultant to close the jaw than would be necessary if the jaws were in a more normal relation. Thus, in this type of malocclusion (where there is a tendency toward a distal displacment of the mandible) greater power is necessary to do the same amount of work than would be required in a more normal relationship of the jaws. This increased force could therefore, be supplied by the masseter muscles since their function is to supply power to the masticatory stroke; and in the electromyographic studies, this increased participation of the masseters is shown in the number of times that they initiate the chewing activity before orthodontic treatment.

B. Analysis of the Chewing Stroke as Expressed as a Percentage of the Chewing Cycle

Previous investigators in this study, Widen (1960), Asahino (1960), Shanahan (1960), Zylinski (1961), and Fleming (1961), believed that the length of the chewing stroke was an indication of the amount of inhibition in the muscles of mastication; and that electromyographically the length of the chewing stroke would become longer as treatment progressed. This condition did persist through Experiment VI. Roth (1962) in Experiment VII first recognized that this pattern did not continue. In the histograms for all experiments to date, what appeared as a trend in the first six experiments gave only a partial picture of what was to happen in this phase.

When all the histograms were examined, it became evident that the middle range of the percentages--those representing a chewing stroke of forty-five to sixty-five percent of the chewing cycle--made up the majority of the lengths of the chewing strokes. The smaller lengths of the chewing strokes, those below twenty-five percent disappeared, but the longer lengths remained, albeit in a lessened amount. Thus, when this data was subjected to the Chi Square Test of significance to determine whether there was a difference in the DISTRIBUTION in the different lengths of chewing strokes between Experiments, a significant difference showed up. This means that in each stage of treatment, the DISTRIBUTION of the LENGTHS of the chewing strokes were different; but does not necessarily mean that the chewing strokes were becoming longer as treatment progressed.

The results of Experiment VIII seem to further substantiate the findings of Roth (1962) that there is an habitual length of time for the chewing stroke and that changes in the sensory environment of the teeth do not affect this habitual relation.

4. Analyzing the Number of Bursts in a Chewing Stroke

Fleming (1961) concluded that the number of bursts in a chewing stroke was a reasonably good electromyographical indicator of the number of times inhibition had taken place in the muscles of mastication. Thus, analyzing the number of bursts in a chewing stroke would indicate whether there was a statistically significant difference between the inhibition in the muscles of mastication in patients wearing appliances in this stage of treatment and the inhibition in the muscles of mastication of those not wearing appliances. This data was subjected to the Analysis of Variance Test for significance and was found to be very significant at the one thousandth percent level of probability. This indicates that, as a result of the appliances on the teeth, there is a measurable amount of inhibition in the muscles of mastication; and that with the removal of the appliances there is less inhibition. This finding,plus the fact the patients without appliances had a muscular behavioral pattern of less bursts and noding and a greater number of synchronous initiation of chewing activity, intimates, that after the malocclusion is corrected, there is better distribution of labor between the muscles and less inhibition. This may be attributed to the better axial inclination and incline plane relation of the teeth, occurring as a result of orthodontic treatment.

When the analysis of variance was used as a tool for analyzing the inhibition that occurred in the muscles, certain other effects were of statistical significance.

There was a statistical difference in the amount of inhibition of the masseter and temporal muscles. Also, the interaction of appliances-times-muscles is significant. These two findings taken together indicate that during treatment either the masseter was more inhibited than the temporal, or vice versa; and that there was a change in the amount of inhibition to the muscles after the appliances were removed. Only the behavior of the masseter as shown in the previous findings agrees with the data garnered from the above findings: that it, rather than the temporal, is more inhibited during treatment and becomes less inhibited when the appliances are removed.

The interaction, appliances-times-sides was also statistically significant. This indicates that during the correction of the Class II molar relation there was more inhibition on one side than the other. This would imply more interference on one side than on the other; it indicates that one side was corrected before the other. (This is usually what appears clinically.) The inhibition of the muscles on the side where the Class II molar relation is not reduced protects the teeth from strong occlusal forces. These forces would be harmful to the teeth when they do not have a good axial inclination and incline plane relation to the opposing arch. This again demonstrates the role of the neuromuscular mechanism in coordinating the muscular action in such a way as to protect the teeth and the surrounding tissues.

CHAPTER V

SUMMARY AND CONCLUSIONS

A. Summary

This study is the seventh part of a longitudinal electromyographic investigation to observe what effect the change, in sensory input to the periodontal sensory receptors, caused by orthodontic treatment, had on the motor output to the muscles of mastication. The effect on the muscles was observed by electromyographical means before, during, and after orthodontic treatment. These electromyographic recordings of the masseter and temporal muscles were taken on sixteen patients presenting varying malocclusions. During each treatment stage, the first three chewing strokes of two chewing exercises of the right and left masseter and temporal muscles were recorded. The records (the myograms of the muscles) were then studied and analyzed.

The chewing medium was Vick's cough drops.

The orthodontic procedures used in this study differ from other orthodontic procedures in that light forces, as distinguished from heavy forces, were used to move the teeth. These light forces came from highly resilient, small diameter archwires and also from latex elastics.

This part of the investigation was concerned with the electromyographic recordings taken during the final stages of treatment, six months after Experiment VII, Part VI of this longitudinal study. In this stage of treatment, nine patients had their orthodontic appliances removed and were using functional retainers. Of the seven remaining, three were having Class II molar relations corrected; three were at the stage of consolidation between the anterior teeth; and one was having the midline of the maxillary teeth corrected to that of the midline of the mandibular teeth. The findings from this part of the investigation (Final Stages of Treatment, Six Months After Experiment VII, Part VI) were compared with the findings previously obtained by the earlier investigators in the longitudinal study. Electromyographic recordings for the longitudinal study were recorded during the following stages in the correction of the malocclusions:

Experiment I	Original Malocclusion
Experiment II	One Day After Placement of Separating Wires Between the Teeth
Experiment III	One Week After Placement of Separating Wires Between the Teeth

Experiment IV	One Week After Placement of the First Archwires
Experiment V	During Anchorage Preparation
Experiment VI	After Completion of Anchorage Preparation
Experiment VII	During the Final Stages of Orthodontic Treatment
Experiment VIII	During the Final Stages of Orthodontic Treatment, Six Months After Experiment VII

The study is not complete at present; and in the near future additional electromyographic recordings will be taken and analyzed by others in order to finish the investigation.

B. Conclusions

1. The number of bursts and the synchronous initiation of the chewing activity best characterize the behavioral change in the muscles.

2. In the orthodontically treated case, the trend is toward a synchronous initiation of the chewing stroke.

3. The length of the chewing stroke varies within an habitual range of forty-five to sixty-five percent of the chewing cycle, and for this reason is a poor indicator of a change in motor output.

4. The masseter is greatly inhibited during the orthodontic procedure

more so than the temporal is; but when the malocclusion is corrected, the masseter is no longer so inhibited and acts in conjunction with the temporal muscle, rather than independently, in initiating the chewing activity.

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C. UNPUBLISHED MATERIAL

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APPROVAL SHEET

The thesis submitted by Dr. H. Gordon Osser has been read and approved by members of the Departments of Anatomy and Oral Biology.

The final copies have been examined by the director of the thesis and the signature which appears below verifies the fact that any necessary changes have been incorporated, and that the thesis is now given final approval with reference to content, form, and mechanical accuracy.

The thesis is therefore accepted in partial fulfillment of the requirements for the Degree of Master of Science.

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